2.0 ANALYSIS

2.1 Analysis Overview

Methodology used:

During the investigation, the accident investigative team, which consisted of Egyptian, French, and U.S. investigators, mutually agreed upon and adopted a "scenario tree" methodology to determine the accident sequence of events.

As part of this methodology, the investigative team identified possible accident scenarios, and sufficient evidence existed for the team to rule out the inapplicable scenarios.

The team then examined the remaining scenarios and the evidence collected during the investigation to determine which scenario most likely explained the accident sequence of events.
This Fault Tree Methodology has been applied for both:

- Technical related issues
- Human Factors related issues

Fault Tree Methodology Breakdown:

1) Define Accident Top Event

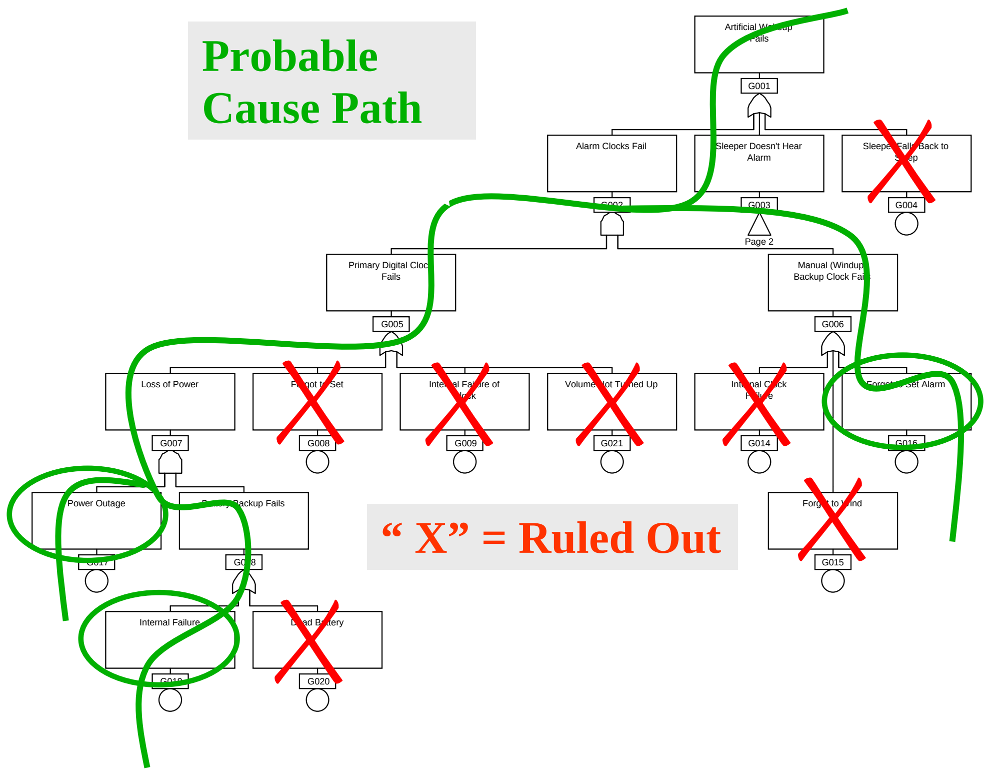
    - Gather Performance, Data Recorders, and Operational Factors Investigators to brainstorm

    - Layout all known evidence and facts related to

    - Develop Sequence of Events if timing of events is known

    - Decide on a description of what went wrong with the aircraft

2) Determine Most Direct Causes
3) Continue Breaking Down Causes
4) Use Facts to Draw Conclusions
5) Define Probable Cause Path



Probable Cause Path
"X" = Ruled Out
Artificial Wakeup Fails
G001
Alarm Clocks Fail
Sleeper Doesn't Hear Alarm
G003
Page 2
G004
Primary Digital Clock Fails
G005
Manual (Windup) Backup Clock Fails
G006
Loss of Power
G007
G008
G009
G021
G014
G016
Power Outage
Battery Backup Fails
G015
Internal Failure
G020

Overview:

The analysis Chapter addresses the following issues:

- Airplane Performance Evaluation

  The performance evaluation was intended to study the behavior of the flight control surfaces as related to the inputs to the flight controls, and the airplane behavior as related to the movement of the control surfaces.

  In order to accomplish this work, Boeing's 737-300 aerodynamic simulation model was used to recreate the accident flight based on the data recorded in the FDR.

  A simulation procedure was used to calculate the response of the airplane to movement of the flight control surfaces.
  Small differences between the simulation and individual airplane's behavior are common and expected due to differences in control surface rigging, engine wear, and other normal tolerances.

  A Kinematic consistency (KINCON) process was used to supplement the FDR data and calculate additional parameters to be used in the performance analysis.

  Information from the airplane performance model, wind tunnel data, flight test data, control surface models, propulsion model, autopilot model, etc, were used.

  A baseline simulation recreation of the accident flight was started just as the airplane turned on to the runway and the throttles were advanced, and the simulation was stopped at the end of the FDR data.

  An examination of the baseline simulation revealed that the path of the accident airplane is consistent with the recorded motion of the control surfaces. Specifically, the extreme bank attitude that occurs towards the end of the flight is consistent with recorded motion of the ailerons.

  A sensitivity analysis was made for one of the airplane parameters (pressure altitude). The analysis showed that the M- Cab computed parameters are quite sensitive to the values of the used input parameters, for example an amount of 65 lb change in the airplane weight would result in a change of the computed altitude by an amount of 200 ft

  Weight and Balance data were analyzed. Analysis revealed a normal airplane loading with correct computations of the airplane weight, c.g. location, stabilizer setting and the Take Off speeds V1, VR, V2.

  Radar data was analyzed. An examination of the Radar data and the FDR data revealed that the path of the accident airplane as derived from the Radar data is consistent with the it’s path as derived from the FDR date

- Analysis of Airplane systems behavior:

  All the airplane systems parameters have been thoroughly examined. All parameters were plotted against time. In several cases, several parameters were plotted together whenever needed to support the investigation. It was noted that several parameters had invalid data.
  All the systems were examined to check there behavior through the flight.

  The M-Cab was used to derive some of the missing data (including the control wheel position). The remaining invalid data did not inhibit the investigation

- Main events in Chronological sequence
  For the sake of the analysis, all the main events were listed in a chronological sequence. These events were used with the fault tree analysis.

- Analysis of the main events

  The methodoly adopted by the investigation team for the analysis was as follows:

  - To collect all pertinent information from the available sources (FDR, CVR, records, manuals, questionaires, etc) and process this data as required.
  - To list and encode the Main events in Chronological sequence
  - To use the facilities associated with the fault tree analysis technique to analyse each individual event.
  - To list all the possible causes and hypothetical conditions leading to each individual event.
  - To rule out all the conditions which seem not pertinent to the event based on systems and human Factors reviews and consider the remaining conditions.
  - To review all the other remaining conditions from the point of view of the systems and the human factors analysis
  - Listing the Pros (issues that support the probabilty of condition occurrence) and Cons (issues that do not support the probabilty of condition occurrence) related to each condition
  - Determining the most probable cause (s) for each individual events

  After several meeting of the investigation team held in:
  - Cairo January 2004
  - Cairo March 2004
  - Paris May 2004

- Seattle September 2004
- Cairo February 2005
- Cairo August 2005

Two studies have been developed by the whole investigation team jointly addressing both the:

- Systems analysis (fault tree)
- Crew behavior

The contents of the study related to the “Systems analysis (fault tree)” is shown in section 2.5

See section “2.6 Crew Behavior”, Thread Overview Updates Cairo 26-Aug-05, Flash Air CBS Sub-group Comments (25 August 2005)”

2.2 Airplane Performance Evaluation:

2.2.1. General

The performance evaluation was intended to study the behavior of the flight control surfaces as related to the inputs to the flight controls, and the airplane behavior as related to the movement of the control surfaces.

In order to accomplish this work, Boeing's 737-300 aerodynamic simulation model was used to recreate the accident flight based on the data recorded in the FDR.

FDR relevant parameters:

Several parameters were recorded in the FDR (related to the aircraft performance including):

- The movements of the pilot's controls:
    - Control column
    - Control wheel position (FDR data is not reliable)
    - Rudder pedals
    - Speed brake handle
- The movement of the primary control surfaces:
    - Elevators
    - Ailerons
    - Rudder
    - Stabilizers
- The movement of the secondary control surfaces:
    - T.E. Flaps
    - L.E. Devices (flaps, slats)
- Motion of the airplane:
    - Pitch
    - Angle of attack
    - Roll attitude
    - Heading angle
    - Drift angle
- Airplane acceleration
    - Vertical
    - Longitudinal
    - Lateral
- Additional parameters, including:
    - Airplane pressure altitude
    - Radio height
    - Computed airspeed
    - Barro corrections
    - Ground speed
    - Total Air Temp
    - Gross weight
    - Wind speed
    - Wind direction
    - Stick shaker condition
    - Present position Lat

- Present position Long

2.2.2 Simulation procedure:

The simulation calculates the response of the airplane to movement of the flight control surfaces – for example, it can calculate the roll rate resulting from a 10 degree deflection of the ailerons. The simulation has been verified by comparison against actual flight test data and was used for the design and certification of the 737-300 airplane. In addition, the simulation is the basis for 737-300 crew training simulators used around the world.

However, and because the 737-300 simulation model is essentially a computer program that represents a nominal airplane with nominal engines, small differences between the simulation and individual airplane's behavior are common and expected due to differences in control surface rigging, engine wear, and other normal tolerances.

FDR data are recorded at relatively low sample rates (most of the parameters are recorded each one seconds) and are recorded from different sources, some of which have inherent biases. Because of these issues, a Kinematic consistency (KINCON) process was used to supplement the FDR data and calculate additional parameters to be used in the performance analysis. Kinematic consistency analysis is a general practice for processing flight data (either flight test data or FDR data) to ensure consistency of position, speed, and acceleration data.

The KINCON Process independent of control surface inputs, it also performs the following:

- Removes constant biases from FDR accelerations
- Ensures corrected acceleration data are consistent with FDR ground speed, drift angle, and altitude
- Can derive parameters not recorded
- Provides calculated parameters with higher sample rates than FDR parameters

Kinematic consistence (KINCON) also models the accelerations and Euler angles as smooth functions which allows more accurate calculation of derivatives

The Kinematic consistency process does not make any assumptions about the aerodynamic properties of the airplane. In fact, the process can be applied to any moving object

Based on the airplane performance model, wind tunnel data, flight test data, control surface models, propulsion model, autopilot model, etc, the primary performance parameters can be derived at time t_1 based on their values at time t_0.
These primary performance parameters include:

- Column
- Wheel
- Pedal
- Pitch
- Roll

- Heading
- Stab
- Thrust
- Flaps
- Gear
- Altitude
- Airspeed

The resulting simulation data can be separated into different categories

1. Math pilot – not calculated using corresponding FDR data for the main primary control inputs (Column, Wheel and Pedal)
2. Kincon Output – kinematically consistent path data (accelerations and angles) for the airplane Euler's angles (Pitch, Roll, Heading)
3. Pass Through Data- FDR data is used directly as an input to simulation for the following parameters
   - Stab
   - Thrust
   - Flaps
   - Gear

   In some cases, a correction is added to improve the simulation match of the path (thrust may be added to better match airspeed)

   For Flash Airlines simulation the stabilizer was adjusted to account for control column bias (2.9° offset), and the throttle lever position was adjusted to improve match of airspeed and altitude

4. Simulator Output – not calculated using corresponding FDR data, but is a direct result of the aero model for parameters like Altitude and airspeed

Pass Through Data:

For Flash Airlines simulation:

- Stabilizer was adjusted to account for control column bias (2.9° offset)
- Throttle lever position was adjusted to improve match of airspeed and altitude

A baseline simulation recreation of the accident flight was started just as the airplane turned onto the runway and the throttles were advanced, and the simulation was stopped at the end of the FDR data. Because the simulation can calculate the response of the airplane to control inputs, a set of control input time histories (column, wheel, and rudder movements) were determined that results in the simulation following the same path as the accident airplane. It is important to note that this process does not use the control or surface position data recorded on the FDR, only the path information (e.g. accelerations, attitude and altitude).

Comparisons between the recorded FDR data and the simulation time history data are provided for longitudinal and lateral/directional data in Figure 1.16.2-1 and Figure 1.16.2-2 respectively.

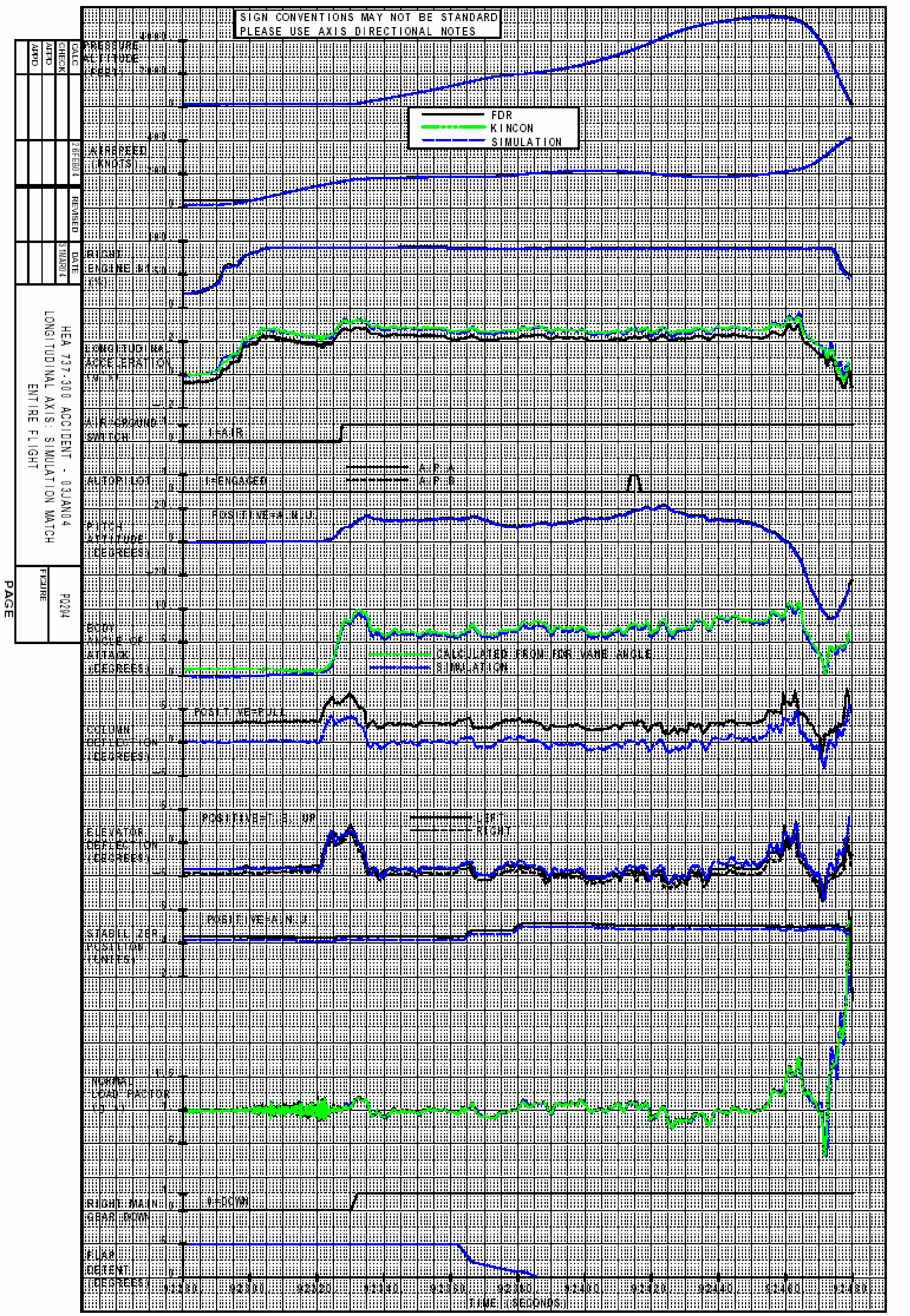


Figure 1.16.2-1 – FDR and Simulation Match Data – Longitudinal Axis

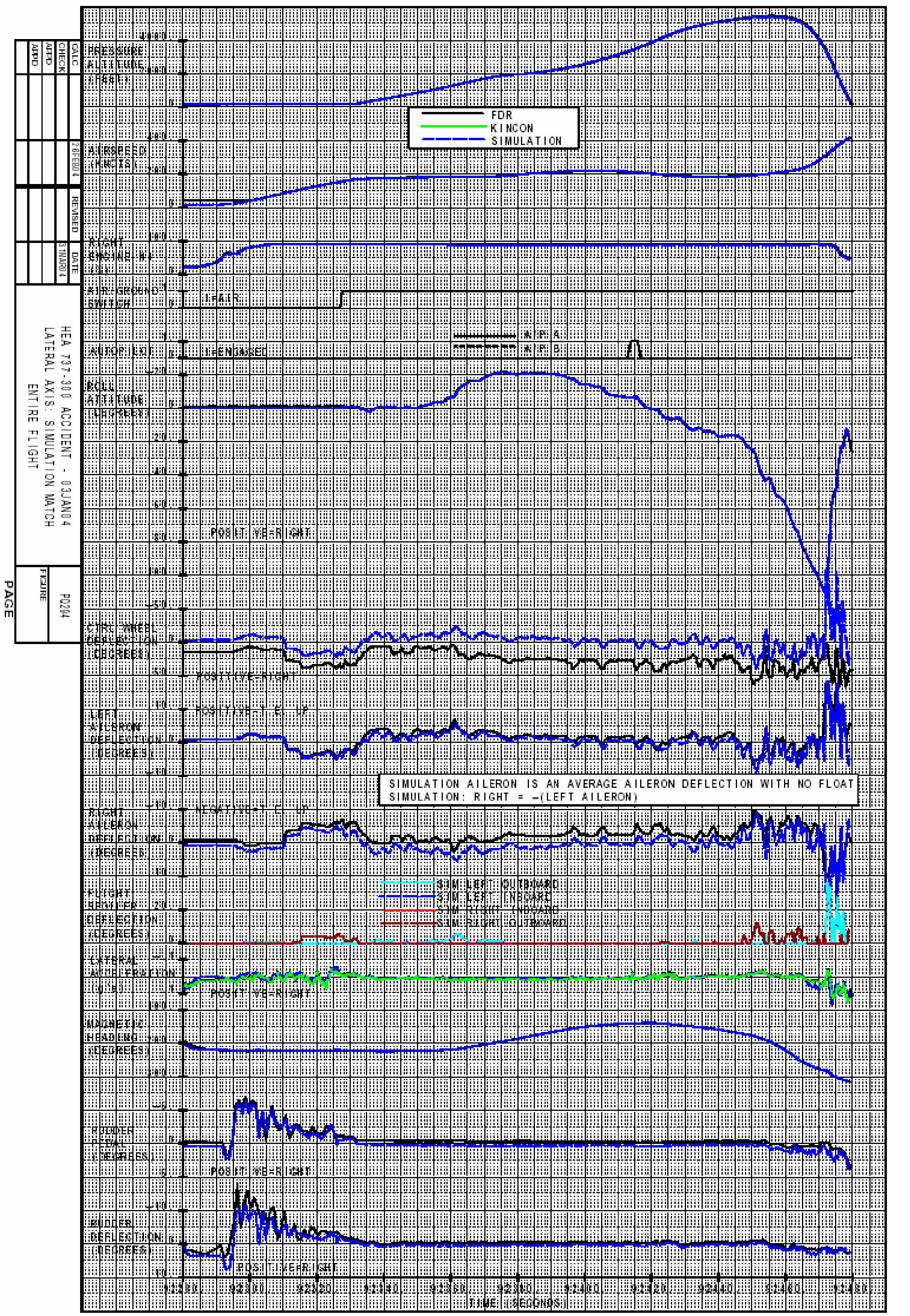


Figure 1.16.2-2 – FDR and Simulation Match Data – Lateral/Directional Axis

An examination of the baseline simulation revealed that the path of the accident airplane is consistent with the recorded motion of the control surfaces. Specifically, the extreme bank attitude that occurs towards the end of the flight is consistent with recorded motion of the ailerons.

Conclusion (Simulation):

Based on the simulation data, the motion of the control surfaces showed consistency with the recorded motion of the control inputs, with the exception of control wheel (because of the unreliable recorded control wheel data)
(See also the conclusion of the sensitivity analysis)

2.2.3 Sensitivity analysis:

Accident flight is approximately 147 seconds long; simulator match of altitude differs by approximately 200 feet (refer to Fig xx Pressure Altitude vs time frames, FDR and Simulation data)

A sensitivity analysis for straight and level flight 147 seconds long was made to determine how much the altitude can be affected by the lift force on the airplane Using Newton 2nd law relating the vertical forces to vertical acceleration and then integrating to get the height z we get

F= M*A

F= L-W

$$\ddot{z} = \frac{L-W}{W}$$

$$z = \iint \frac{L-W}{W} dt^2$$

For constant weight

$$z = g\,\frac{L-W}{W}\,\frac{t^2}{2}\Bigg|_{t_1}^{t_2}$$

Assume altitude error is result of incorrect lift

$$\Delta z = g\Delta\frac{L-W}{W}\,\frac{t^2}{2}$$

Solve for ΔL

$$\Delta L = \frac{2W\Delta z}{g\,t^2}$$

By substitution, it can be noted that
A 65 lb error in calculated lift will result in an altitude error of 200 ft after 147 seconds.

(Refer to section 1.16.1.0 Tests and researches conducted by Boeing and Honeywell, Kinematic Consistency)

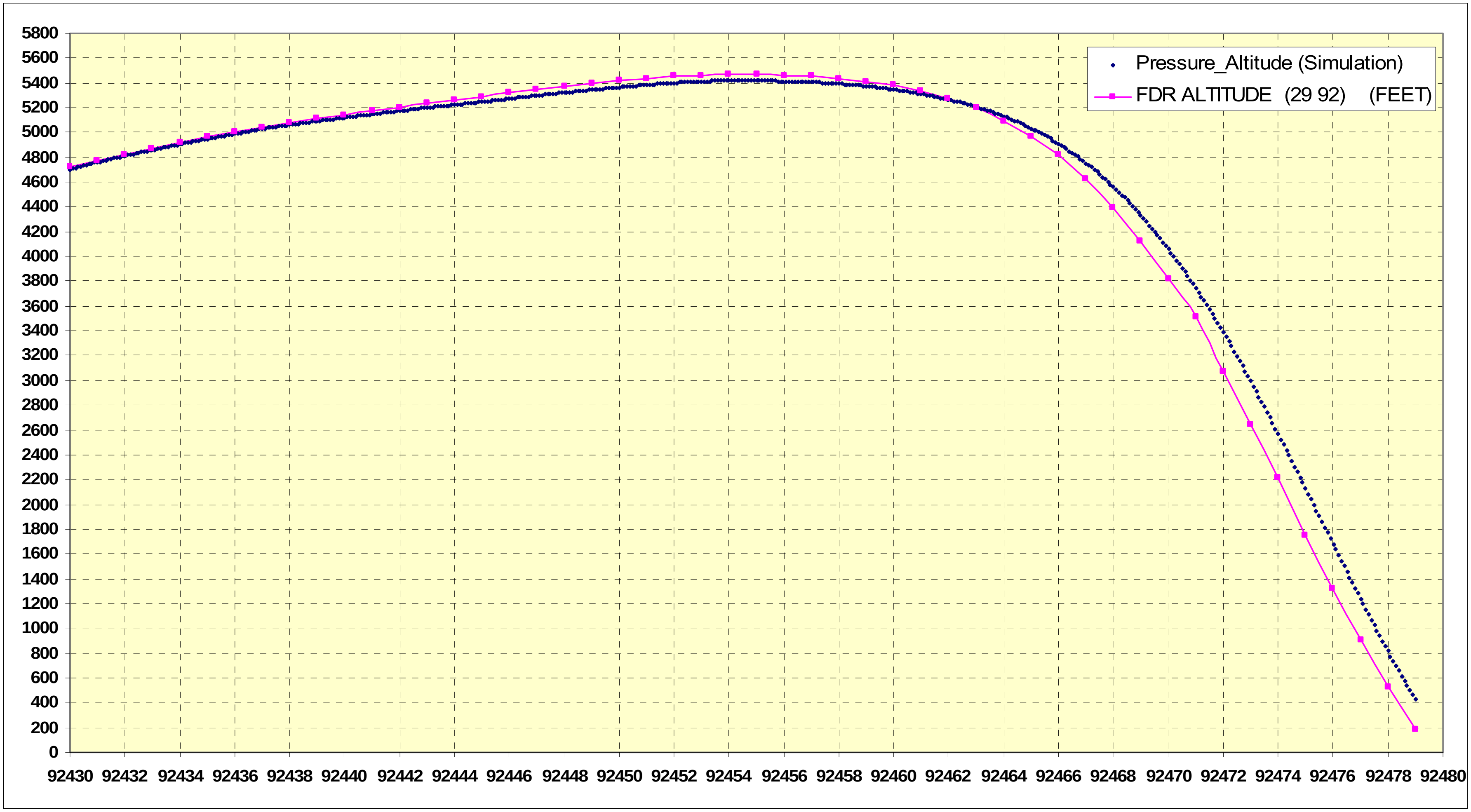


Fig 2.2.3.1 Pressure Altitude vs time frames (FDR and Simulation data)

Conclusion (Sensitivity analysis):

The results obtained from the M-Cab tests indicate that the computed parameters are quite sensitive to the values of the used input parameters, for example an amount of 65 lb change in the airplane weight would result in a change of the computed altitude by an amount of 200 ft[1]

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[1] Altitude was not one of the primary parameters matched for the M-cab simulations. Rather, it is the result of the simulation attempting to match pitch attitude and vertical acceleration. Very small differences in column command would result in a more exact match of altitude, at the expense of matching pitch attitude

2.2.4 Weight and Balance[2]

Although the average weight for passenger used in Load and Trim sheet for the Weight and Balance calculation was not the one given in the airline Flight Operations Manual, none of the available data relevant to the airplane weight and balance showed evidences of airplane loading abnormality. Computations of the airplane weight, c.g. location, stabilizer setting and the Take Off speeds V1, VR, V2 were correct.

[2] See Chapter 1 Factual information Exhibit D Airplane Performance Group Factual Report, section C6 Weight and Balance

2.2.5 Analysis of Radar data:[3]

In the following Figures the aircraft path (indicated by Lat-Long and x-y coordinates) based on radar data is shown

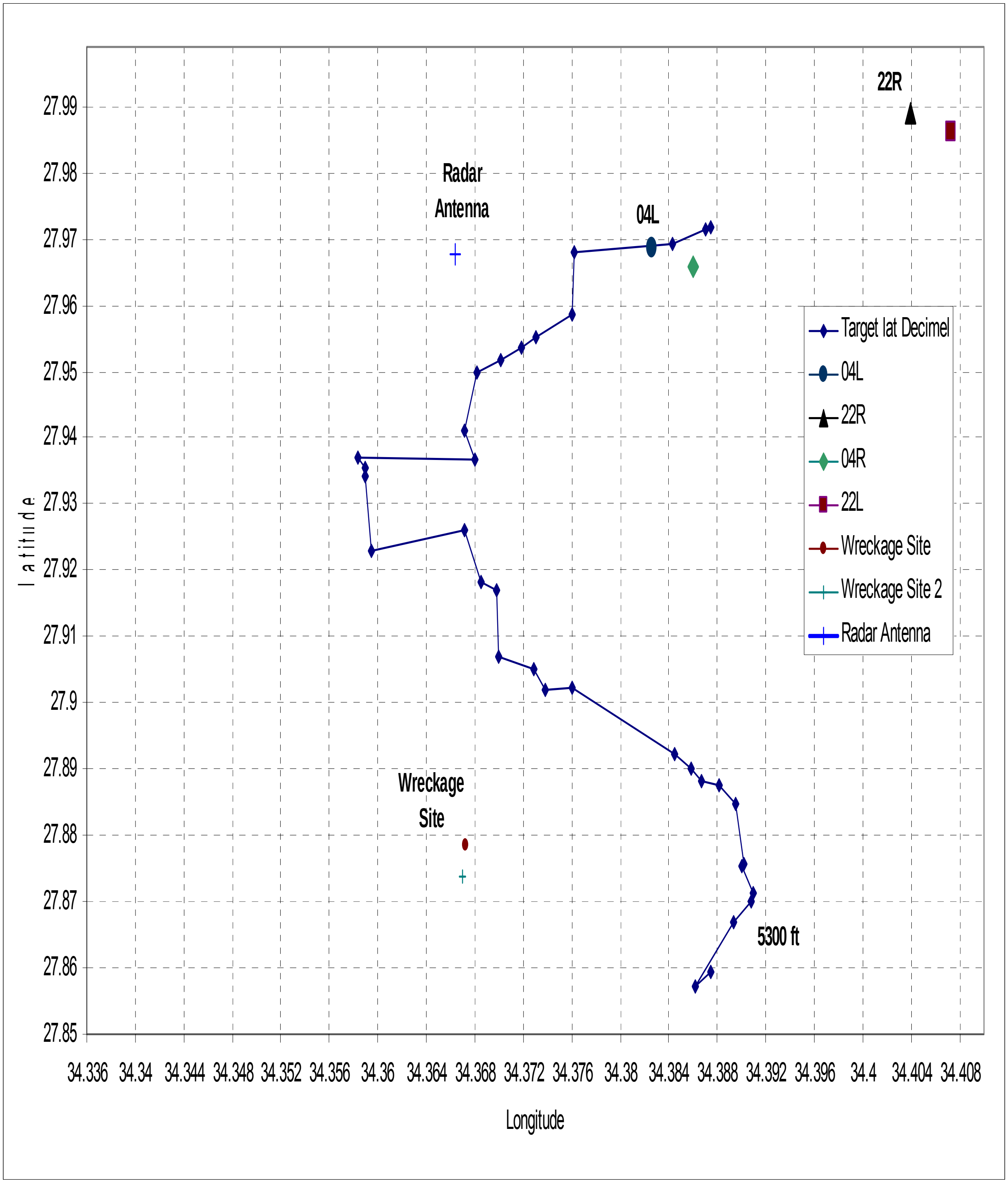


Figure C.2-1 Radar Data Plot, Sharm El Sheik Radar

[3] Refer to Factual report section 1.8 and Exhibit D (Radar Data Analysis)

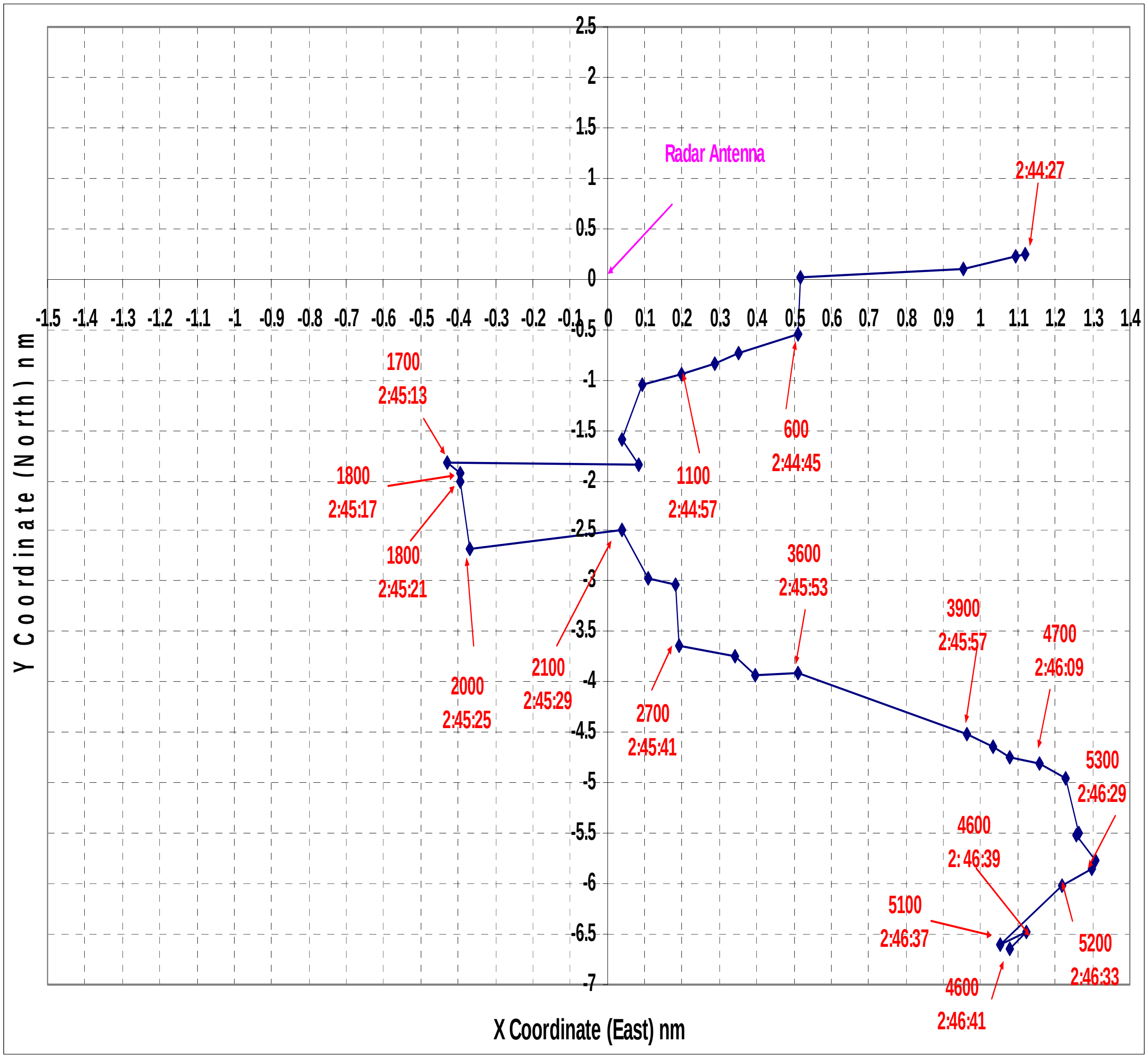


Fig C.2-1a Coordinates (Derived from Radar Data)

(Latitude and longitude coordinates, are transformed into this coordinate system using the WGS84 ellipsoid model of the Earth).

It is noted that the time scale of the radar is not exactly in match with the time scale of FDR. Based on the FDR timing, the airplane crashed in the water at 02:45:06 GMT (92480), while the radar indicated airplane disappearance at 02:47:27 GMT (about 141 seconds later). The last radar return from the airplane which can be considered as reliable was at 02:46:39 Radar time (about 92467 second frames on

the FDR data based on the altitude data). The airplane altitude shown was 4600 ft. The radar data did not show any further smaller altitudes.
The letter n was shown on the Radar data starting from 02:46:47 radar time (about 92475 second frames on the FDR)
The letter n indicates that mode C altitude has not been updated for approximately 7.5 seconds and is considered unreliable, aircraft is below adapted transition level and altitude is in hundreds of feet above mean sea level

Conclusion (Radar data):

An examination of the radar data and the FDR data showed that the path of the accident airplane as derived from the radar data is consistent with the path as derived from the FDR date

2.3 Analysis of Airplane systems behavior:

2.3.1 Environmental Control System (ECS)

The FDR records some parameter related to ECS including:

- ECS packs status (On/ Off, Low/ High)
- Isolation valve poaition (Closed/ Open)
- Cabin pressure altitude (if higher than 10,000 ft)

Based on FDR data and CVR recorded information, there is no evidence of ECS system failure or abnormal behavior. Thus, the ECS system does not have any relation with the accident.

2.3.2 Fire

The FDR monitors the following for conditions of fire:

- Engine 1 and 2
- APU
- Wheel well
- Lavatory (monitors for smoke)

Based on FDR data and CVR recorded information, there is no evidence of any fire condition in the engines, APU, the lavatories nor the wheel well..

2.3.3 Flight controls

The Following parameters were recorded in the FDR

:Analog Data:

- Ailerons positions (Degrees)
- Elevators position (Degrees)
- Pitch Trim position (Degrees)
- Rudder position (Degrees)
- TE Flaps position (Degrees)
- Control wheel position (Degrees)
- Control Column position (Degrees)
- Rudder Pedal position (Degrees)
- Speed Brake Handle position (Degrees)

▪ Discrete Data

- Alternate Flaps switch position
- L.E Flaps # 1,2,3,4 status (Extend, In Transit)
- L.E Slats # 1,2,3,4,5,6 status (Full Extend, In Transit, Mid Extend)

Close observation of the flight controls parameters showed the following:

- Some parameters values were unreliable
  - Aileron control wheel
  - Slat # 1 (showed mid extend position from the very beginning)

- The two ailerons shows a bias of about one degree TEU (Trailing Edge Up) before airborn. After airborn, the bias changed to about 2.7 degrees. (The changes in aileron position bias could be caused by the Airload on the aileron reacting against the wing cable run between the aileron and aileron PCU. Therefore, the bias in aileron position is due to aileron hinge moment which varies as a function of airspeed).

- The Pitch trim reading indicated a constant bias from the expected trim position. This bias was corrected in the M- Cab tests.

- Because the spoiler surface positions are not recoreded in the FDR, any possible abmormality with the spoiler surfaces data can not be shown by the FDR.

- For the consistency analysis between the airplane behavior and the flight control surfaces, See section 2.2 Airplane Performance evaluation.

- A full analysis of the aircraft lateral control system has been done (refer to appendix 2-1 lateral control analysis). All the hypothetical failures in the system have been comprehensively studied All the scenarios resulting from each individual failure (or combination of particular failures) were checked against the accident scenario. Most of the hypothetical failures scenarios were ruled out because of there inconsistency with the accident scenario. The remaining hypothetical scenarios were further examined because they could not be excluded based on a review of FDR data.These hypothetical failures scenarios are as follows [1]:
  - Both trim switches are stuck closed in the same direction:
  - Autopilot actuator, both Solenoids and Transfer Valve Jammed (Actuator Hardover without Force Limiter 17 to 20 lb Force)
  - (Spoiler wing cable jam) offset of the neutral position at time 92450 (maximum wheel deflection).and clears at 92472
  - (F/O wheel jam) offset of the neutral position at time 92450 (maximum wheel deflection).and clears at 92472

2.3.4 Fuel system:

The Total Fuel Mass is the only parameter recorded in the FDR. It is sampled each 64 seconds. Only three samples were recorded as follows:

Time (seconds)	Total Fuel Quantity (KGS)
92304	6404.732

[1] See the complete analysis in section "2.5.13 Right roll continues to overbank with ailerons activities, the lateral control system"

92368	6858.325
92432	6549.882

The amounts of fuel in each individual tank are not recorded in the FDR. Thus the FDR fuel information does not identify any condition of fuel assymetry (if any)

The fuel mass as recorded in the Load Sheet was 7000 kg. It is noted that the FDR showed some slight increase in the Total Fuel Quantity between 92304 and 92368 (about 450 Kg). Change of airplane attitude and the airplane acceleration could explain these abnormal changes.

However, the available information indicates that the fuel system did not have any relation with the accident

2.3.5 Hydraulic system

The FDR records some parameter related to Hydraulics including:

- Systems pressure (system A and system B)
- Hydraulic pumps output pressure status (A hydraulic pumps, B hydraulic pumps, standby pump)

(Sample rate is 64 seconds)

Close observation of the hydraulics parameters showed the following:

- The System pressure recorded for both system A and system B were unreliable (press values were above 5000 psi)
- Hydraulic pumps output pressure status (A hydraulic pumps, B hydraulic pumps, standby pump) showed “No Low Press” status
- Sys A hydraulic loads (Landing Gears, T.E. flaps. L.E. Devices) were driven to the commanded positions.
- Flight control surfaces (powered by A and B systems) showed several movements through out the whole flight.

Based on the FDR available date, there is no evidence that the hydraulic systems do not have any relation with the accident.

2.3.6 Landing Gears

The Following parameters were recorded in the FDR (Sampling rate was each one second)

- Brake Press (Left, Right)
- Gear Position (Nose, L main, R main)
- Gear Red Warning Light (Nose, L main, R main)
- Air/ Ground (Main, Nose)
- Wheel Well Fire
- Main/ Alt Brake Switch

Close observation of the engines parameters showed the following:

- Wheel Well Fire recording is unreliable (always changing between Fire and No-Fire status)
- Gear Red Warning Light (Nose, L main, R main) showed red warning at the time of retarding the throttles levers. This condition could be normal with Landing Gears in the up position.

Based on the FDR available date, there is no evidence that the landing gears have any relation with the accident.

2.3.7 Power plants

The FDR records the following parameters for both engines:

- N1 (%RPM)
- N2 (%RPM)
- FUEL FLOW
- THRUST LEVER ANGLE

- ENG OIL PRESSURE
- ENG OIL QUANTITY
- OIL TEMP

- ENGINES CUTOFF LEVER Position Status
- ENGINES FIRE Status

- ENGINES T/R L, R SLEEVE DEPLOYED Status
- ENGINES T/R L, R SLEEVE NOT STWD Status

- CN1 (Low Press Compressor) TRACKED VIB
- CN2 (High Press Compressor) TRACKED VIB
- TN1 (Low Press Turbine) TRACKED VIB
- TN2 (High Press Turbine) ACCEL SRC
- FAN IMB ANGLE

- COWL ANTI ICE Status
- ENGINE BLEED Status

- PMC (Power Management Computer) Status

- GO AROUND N1 (%RPM)
- MAX CONTINUOUS N1 LIMIT (%RPM)
- MAX CLIMB N1 LIMIT (%RPM)
- MAX CRUISE N1 LIMIT (%RPM)

- N1 BUG DRIVE (%RPM)
- TARGET N1 (%RPM)

Close observation of the engines parameters showed the following:

- Some parameters values were unreliable
    - CRUISE N1 LIMIT #2
    - N1 L
    - ENG 1 CUTOFF lever position
    - ENG 2 CUTOFF lever position

- All T/R Sleeves Showed stowed and locked position

- Engine bleeds were on

- Based on N2 comparison for both engines, the two engines showed symmetrical thrust

- Engines power were reduced at about 92472 timeframe (seconds) (consistent with CVR announcements) The left engine PLA data indicated slight throttle lever advancement at 92477 ending at 92479

- Both PMC's (Power Management Computer) were On.

- Fire discrete parameters indicated "No Fire" in the engines

Based on the FDR available date, there is no evidence that the engines have any relation with the accident.

2.3.8 APU

Only the APU FIRE status was recorded in the FDR

Based on the FDR available date, there is no evidence that the APU has any relation with the accident.

2.3.9 Auto Flight & Communication:

The Following parameters were recorded in the FDR (Sampling rate was each one second in most cases):

Analog Parameters:

- DH SEL (FEET)
- DISTANCE TO GO (NM)
- DME DISTANCE L (NM)
- DME DISTANCE R (NM)
- G/S DEV EFIS (DDM)
- LOC DEV EFIS (DDM)
- SEL AIRSPD FCC L (KNOTS)
- SEL ALT FCC L (FEET)
- SEL COURSE 1 (DEG)
- SEL COURSE 2 (DEG)
- SEL HEADING FCC L (DEG)
- SEL MACH FCC L (MACH)
- VOR/ILS FREQ L (MHz)
- VOR/ILS FREQ R (MHz)

Discrete parameters

- Range Selection Status (Captain, F/O)
- A/P Off Status
- A/P Warning Status
- A/T Engage Status
- A/T GA Status
- A/T Limit Status
- A/T Manual Disconnect Status
- A/T MCP Speed Engagement Status
- A/T MIN Speed Engagement Status
- A/T N1 Engagement Status
- A/T Retard Engagement Status
- A/T Warning Status
- AIRPORTS Select Status (Captain, F/O)
- ALT ACQ FCC Engagement Status
- ALT HOLD FCC Engagement Status
- APPROACH FCC Engagement Status
- CMD A FCC Engagement Status
- CMD B FCC Engagement Status
- CWS A FCC Engagement Status
- CWS ROLFCC L Engagement Status
- DONT SINK Status
- EFIS /NON EFIS Selection
- EFIS SEL SW CAPT Status
- EIS /NON EIS Status
- EVENT MARKER Status
- F/D A ON FCC Status
- F/D B ON FCC Status

- FLARE ENGA FCC (0-. 1-ENGA)
- FMC SEL SW Status (Captain)
- FMC/IRU DATA SOURCE Selection(0-IRU 1-FMC)
- FULL COMPASS ROSE Selection (Captain, F/O)
- G/S ENGA FCC Engagement Status
- G/S GPWS Status
- HDG SEFCC L Engagement Status
- HF KEYING Selection (Left, Right)
- ILS (MOD) Selection (Captain, F/O)
- ILS (STD) Selection (Captain, F/O)
- INNER MARKER Status
- IRS SEL SW Selection (Captain)
- L NAV ENGA FCC Engagement Status
- LEVEL CHANGE FCC Engagement Status
- LOCAL LIMITED MASTER Setting Status
- MAP MD SEL Status (Captain, F/O)
- MASTER CAUTION Status.
- MCP SPEED FCC Engagement Status
- MIDDLE MARKER Status
- MINIMUMS Status
- MLS SEL (Left and Right) Selection
- NAV AIDS Selection Status (Captain, F/O)
- NAV MODE SEL Status (Captain, F/O)
- OUTER MARKER Status
- PLAN MD SEL Status (Captain, F/O)
- PULL UP Status
- ROUTE DATA SEL (Captain, F/O)
- SCAN DME / NON SCAN DME Status
- SINGLE CHANNEL FCC L Engagement Status
- SINK RATE Status (0-. 1-TRUE)
- STICK SHAKER Status (Left and Right)
- TERRAIN Status
- TERRAIN PULL UP Status
- TO/GA FCC Engagement Status
- TOO LOW FLAP Status
- TOO LOW GEAR Status
- TOO LOW TERRAIN Status
- TRIM DN A/P Trim Status
- TRIM DN MAN Trim Status
- TRIM UP A/P Trim Status
- TRIM UP MAN Trim Status
- TRUE / MAG SW Selection Status
- V/S MODE FCC Engagement Status
- VHF C KEYING Status (Left, Center, Right)
- VOR (STD) SEL Status (Captain, F/O)
- VOR MD SEL Status (Captain, F/O)
- VOR/ILS SEL Status (Left, Right)
- VOR/LOC ENGA FCC Engagement Status
- WAY POINT SEL Status (Captain, F/O)
- WINDSHEAR Status
- WINDSHEAR CAUTION Status

- WXR DATA Selection Status (Captain, F/O)
- YAW DAMPER DISENGAGE Status
- A/P OFF FCC Status
- A/P WARNING Status
- CMD A FCC Engagement Status
- CMD B FCC Engagement Status
- CWS A FCC Engagement Status
- CWS ROLL FCC L Engagement Status
- HDG SEL FCC Left Engagement Status

Close observation of the Autoflight Systems showed the following:

- A/P OFF FCC status showed ON condition at 92413 and then OFF Condition at 92416
- CMD A FCC Status showed an engagement condition at 92413 and then disengagement at 92416
- A/P WARN status showed warning condition at 92416, the warning ended at 92417
- A/T ENGA showed engagement status throughout the flight.
- A/T MAN DISC showed no manual disconnection
- A/T N1 showed disengagement condition up to 92295, then A/T N1 showed engagement condition up to 92308. A/T N1 remained disengaged in the interval between 92309 and 92355, after that A/T N1 remained Engaged.
- CWS ROLL FCC L showed engagement condition at 92413, then disengagement at 92416
- FD A ON FCC, FD B ON FCC showed ON condition throughout the whole flight.
- HDG SEL FCC L showed engagement condition at 92341 up to 92413. HDG SEL FCC L was disengaged at 92414 up to 92421. After that it remained engaged till the end of the flight
- LEVEL CHANGE FCC showed engagement status at 92344. Engagement condition remained till the end of the flight
- Course selected was 306 (sampled every 64 seconds)
- Heading selected was ~360 degree (at 92323) followed by ~107 degree (at 92387) then ~ 85 degrees (at 92451). Heading was sampled every 64 seconds.
- VOR selection was 114.2 MHz
- MCP SPEED FCC showed engagement condition at 92344. Engagement condition remained till the end of the flight
- TOGA FCC showed an engagement condition only for 2 seconds (92296, 92297)
- WINDSHEAR and WINDSHEAR CAUTN did not show any condition of Windshear.

Full analysis of the main events related to Auto Flight Systems has been carried out. (See section 2.5. Anaysis of the chronological main events.)

2.3.10 Miscellaneous:

- Master Warning

FDR data Showed "Master Warning On" status at 92465

Conditions resulting in Master Warning condition are indicated in the following table:

Master Caution Discrete at Time 92465

Group	Condition	Rating
Flight Controls	Low Quantity	2
	Low Pressure	2
	Feel Diff Press	2
	Speed Trim Fail	1
	Mach Trim Fail	1
	Yaw Damper	3
	Autoslat Fail	2
Hydraulics	Low Press – Elec Pump	3
	Overheat – Elec Pump	2
	Low Press – Eng Pump	3
IRS	Fault	2
	On DC	2
	DC Fail	2
Fuel	Low Pressure	1
	Filter Bypass.	3
APU	Low Oil Pressure	2
	Fault	2
	Overspeed	1
Electrical	Low Oil Pressure	2
	High Oil Temp	2
	Standby Power Off	2
	Transfer Bus Off	3
	Bus Off	3
Overheat Detection	Engine1 overheat	2
	Engine 2 overheat	2
	APU Detection Inop	1
Anti-Ice	Window overheat	2
	Pitot heat	2
	Cowl Anti-Ice	3
Doors	Fwd/Aft Entry	1
	Equipment	1
	Fwd/Aft Cargo	1
	Fwd/Aft Service	1
	Airstairs (not installed on PQ294)	
Engine	Reverser	3
	PMC-Inop	1
	Low Idle	1
Overhead	Equipment Cooling - Off	2
	Emer Exit Lts-Not Armed	2
	Flight Recorder - Off	3
	Pass Oxy - On	3
Air Cond	Flt Deck Duct Ovht	2
	Pax Duct Ovht	2
	Dual Bleed	2
	Wing-Body Overheat	2
	Bleed Trip Off	2
	Auto Fail	2
	Off Sched Descent	1
	Pack Trip Off	2

Legend
1 = unknown
2 = unlikely
3 = ruled out

All the above conditions can result in Master Caution activation. Based on the available data, it is hard to identify one individual fault as the cause of this event.

2.4 Main events in Chronological sequence

Based on the information collected from the FDR and the CVR, a sequence of the main events that occurred during the accident flight has been established. These main events are:

1.0 TO/GA Mode Disengage

2.0 Aileron Movement during Take Off

3.0 FD Modes (Pitch-Roll Re-engagement

4.0 Roll Left, and Left Turn Begun

5.0 Roll Back towatrds Wing Level

6.0 Pitch Up and Airspeed Decay

7.0 Autopilot Engage Sequence

8.0 Mode Change from “HDG SEL” to “CWS-R”

9.0 Ailerons Move in Direction of Right Roll

10.0 Auto Pilot Disengagement Indication on FDR

11.0 Airplane Brgins Roll to Right

12.0 Heading Select Engaged

13.0 Right Roll Continues to Overbank with Aileron Activity

14.0 F/O Autopilot announcements (CVR)

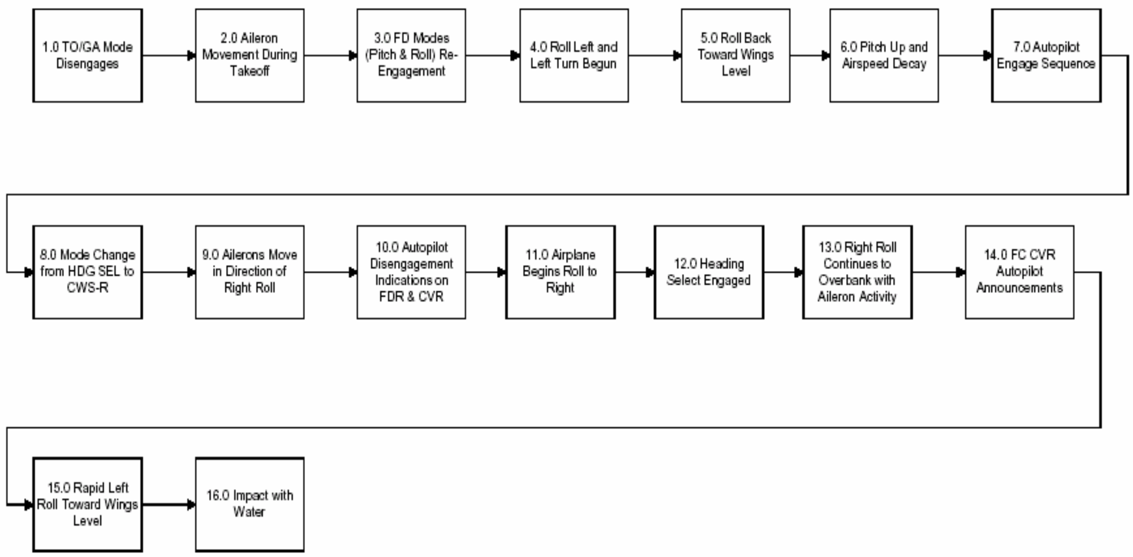
15.0 Raoid Left Roll Towards Wing Level

16.0 Impact with Water

Flash Airlines Sequence of Events - DRAFT

Seattle Edits Adapted from May 2004 Paris Meeting

10/1/04



2.5 Anaysis of the chronological main events

2.5.1 TO/GA Mode Disengages:

2.5.1.1 FDR Data:

FDR data shows TOGA on one side for only 1 or 2 seconds, other side unknown (all 13 flights with both A and B for different flights): for the accident flight, the TO/GA Mode was engaged at 92296 second, and was disengaged at 92297 second

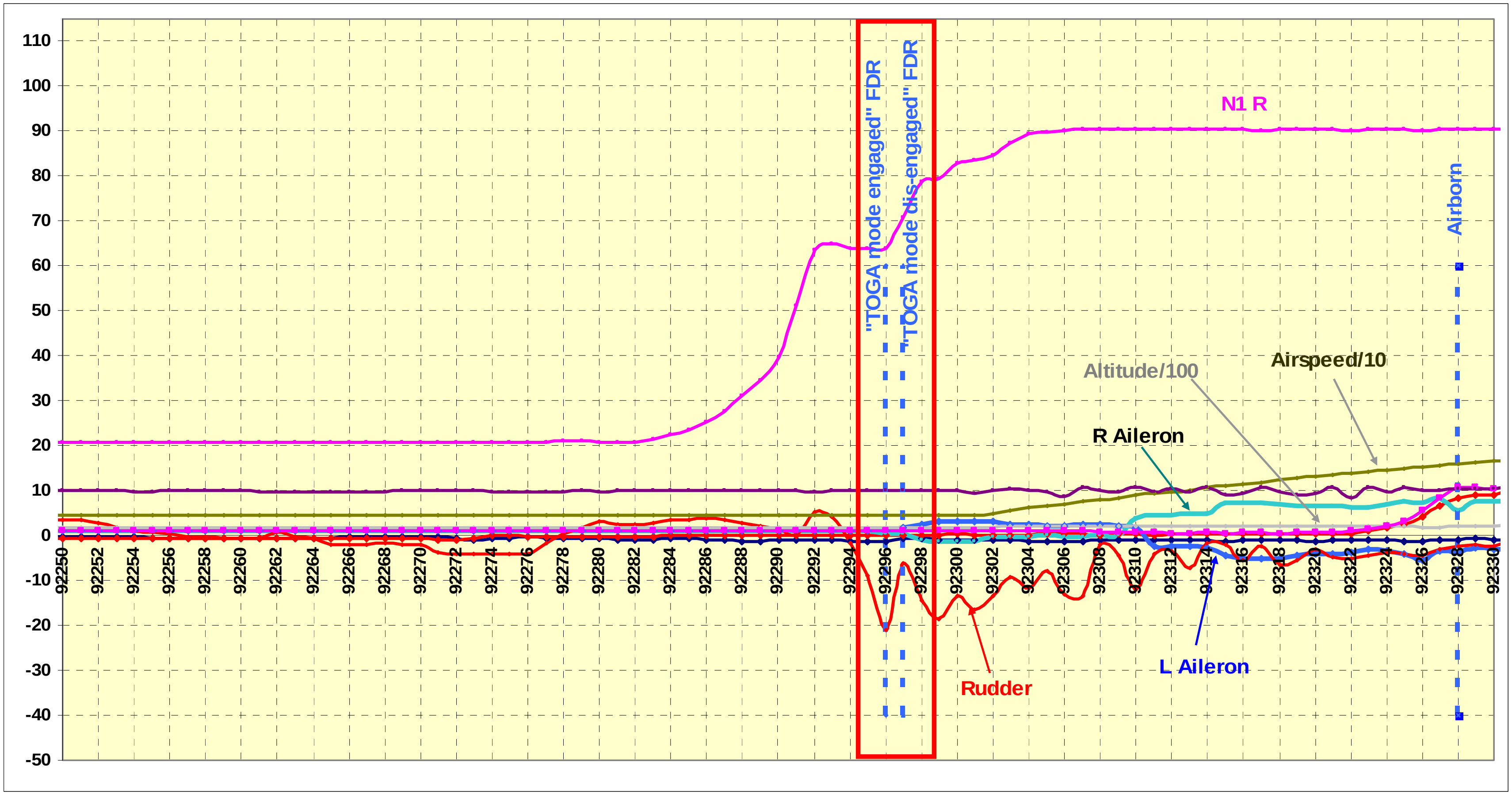


Figure 2.5.1.1a TO/GA Mode Disengages (FDR data)

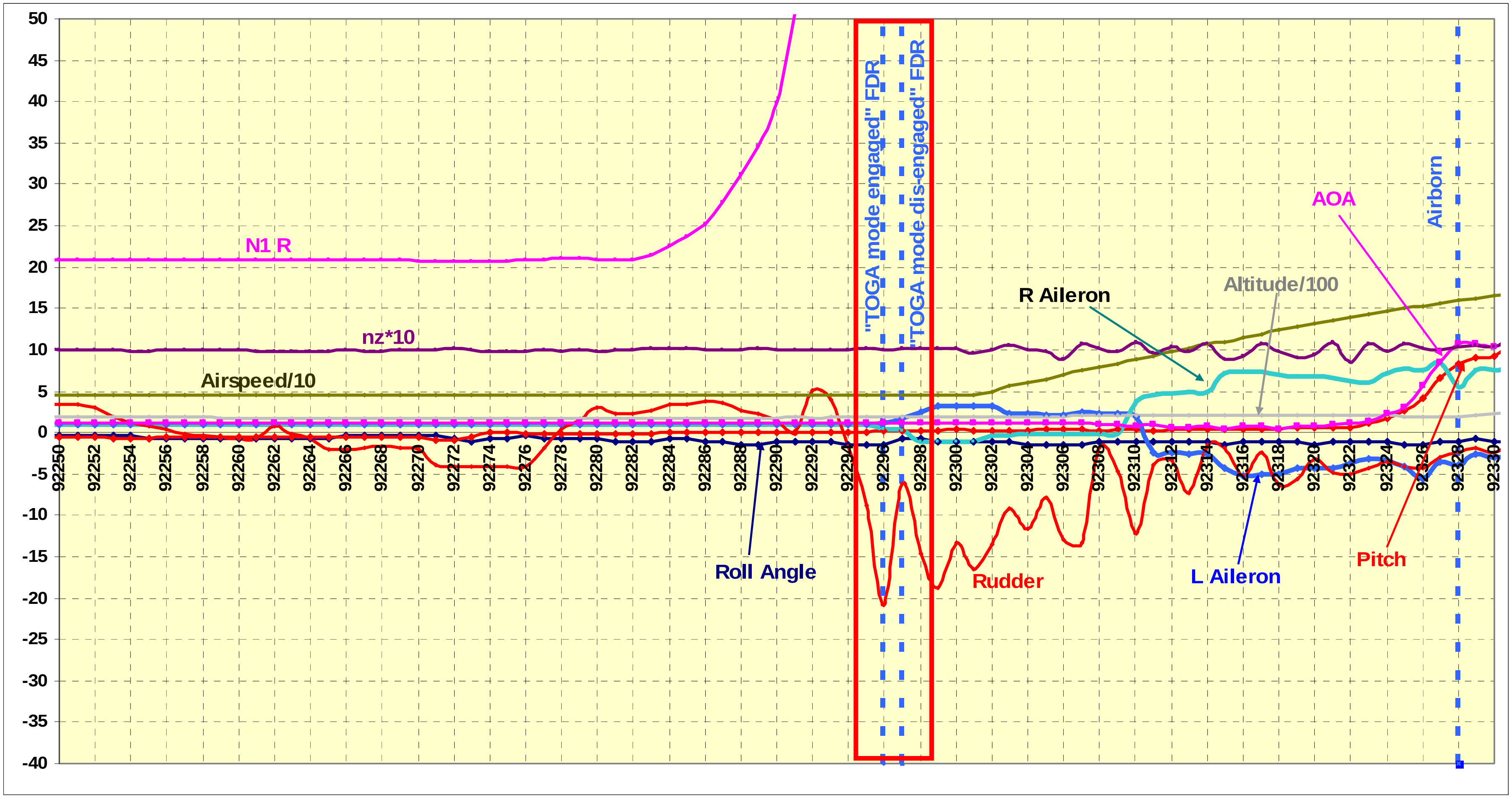


Figure 2.5.1.1b TO/GA Mode Disengages (FDR data)

TO/GA Observation within the last 25 Hours:

SU-ZCF – FDR 25 Hour Data

TOGA Observations

Flight	Both F/D ON?	Normal looking A/T Takeoff	First TOGA Push (1)	If Second TOGA Push (1)
1	YES	YES	1	2
2	YES	YES	0	
3	YES	YES	2	
4	NO	YES	0	
5	YES	YES	2	
6	YES	YES	1	
7	YES	YES	1	
8	YES	YES	2	
9	YES	YES	2	1
10	YES	YES	0	
11	YES	YES	2	
12	YES	YES	2	
13	YES	YES	2	

(1) Number of samples recorded for TOGA_FCC (sample intvl=1 sec)

2.5.1.2 TO/GA Modes and Logic (Takeoff Mode Logic)

- Takeoff mode provides thrust control during the initial phase of the takeoff roll (0 to 80 knots).
- The takeoff mode is set by the takeoff/go-around switch, with the A/T armed for takeoff. The A/T is armed for takeoff when the airplane is on the ground, the Autothrottle is engaged, and the FMC takeoff mode is executed. If the A/T is engaged in go-around, the takeoff mode is inhibited. The takeoff mode is reset when the throttle hold logic is set, or the Autothrottle is disengaged.

(Refer to Boeing MM Chapter 22-31-00, Page 32)

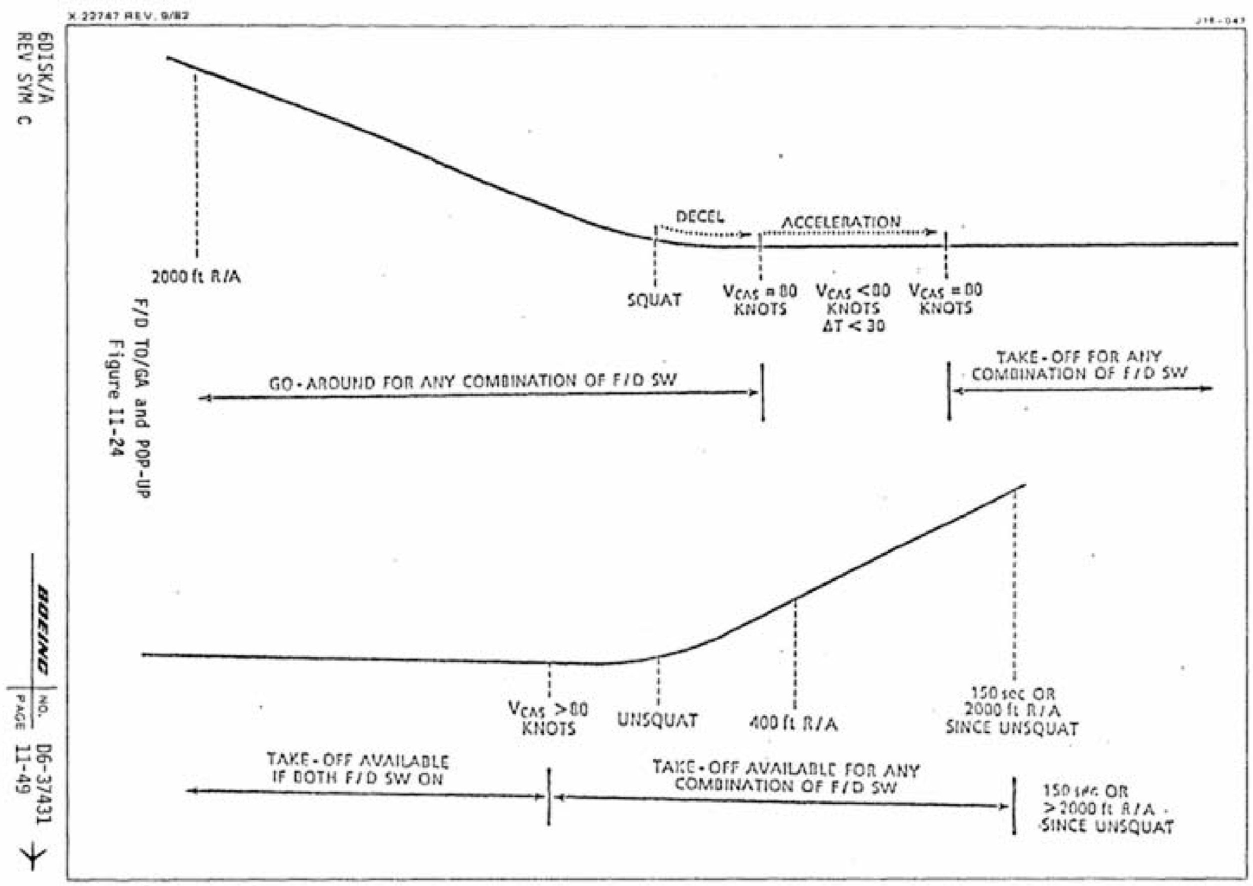


Fig 2.5.1.2 Take Off Mode

2.5.1.3 TO/GA Mode Disengage Logic:

The TO/GA Mode disengages during the Take Off mode if the following logic is satisfied:

{(Airspeed < 80 knots). [(One bad F/D switch input to one FCC) + (Bad squat switch input to one side) + (Landing gear up indication on one side)} + {(IRS instrument transfer switch in Both on X) + (Sensor signal invalid on one side) + (EFIS select switch in Both on X)}

(Refer to Fig 2.5.1.3 TO/GA Mode Disengage Logic[1])

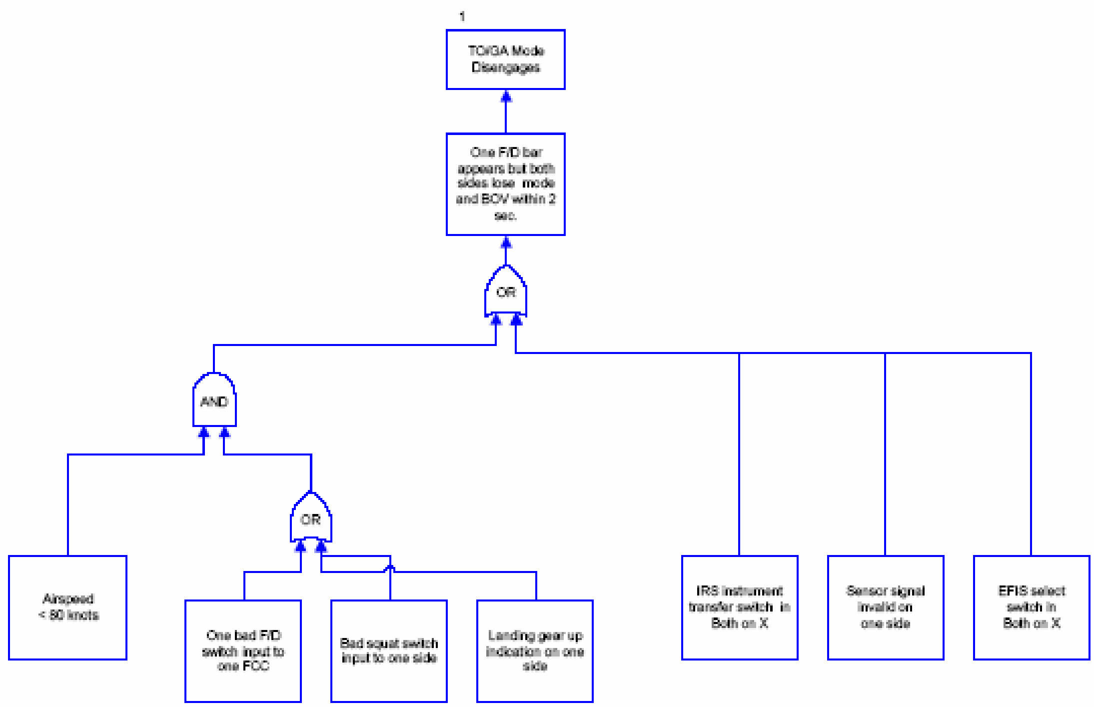


Fig 2.5.1.3 TO/GA Mode Disengage Logic

[1] Data forwarded by Boeing during Cairo meeting, February 2005

2.5.1.4 TO/GA Mode Disengages analysis:

- FCC takeoff mode has not been operating properly for the entire 25 hours recorded on the FDR. Based on FDR data available, the cause for this either a bad squat switch (landing gear compressed) input to one FCC or a bad landing gear position indication to one FCC. In either case, the results is that pressing the TOGA button during takeoff would result in one FCC entering takeoff mode while the other enters go-around mode. This disagreement is detected and results in both FCCs dropping the TOGA mode[2].

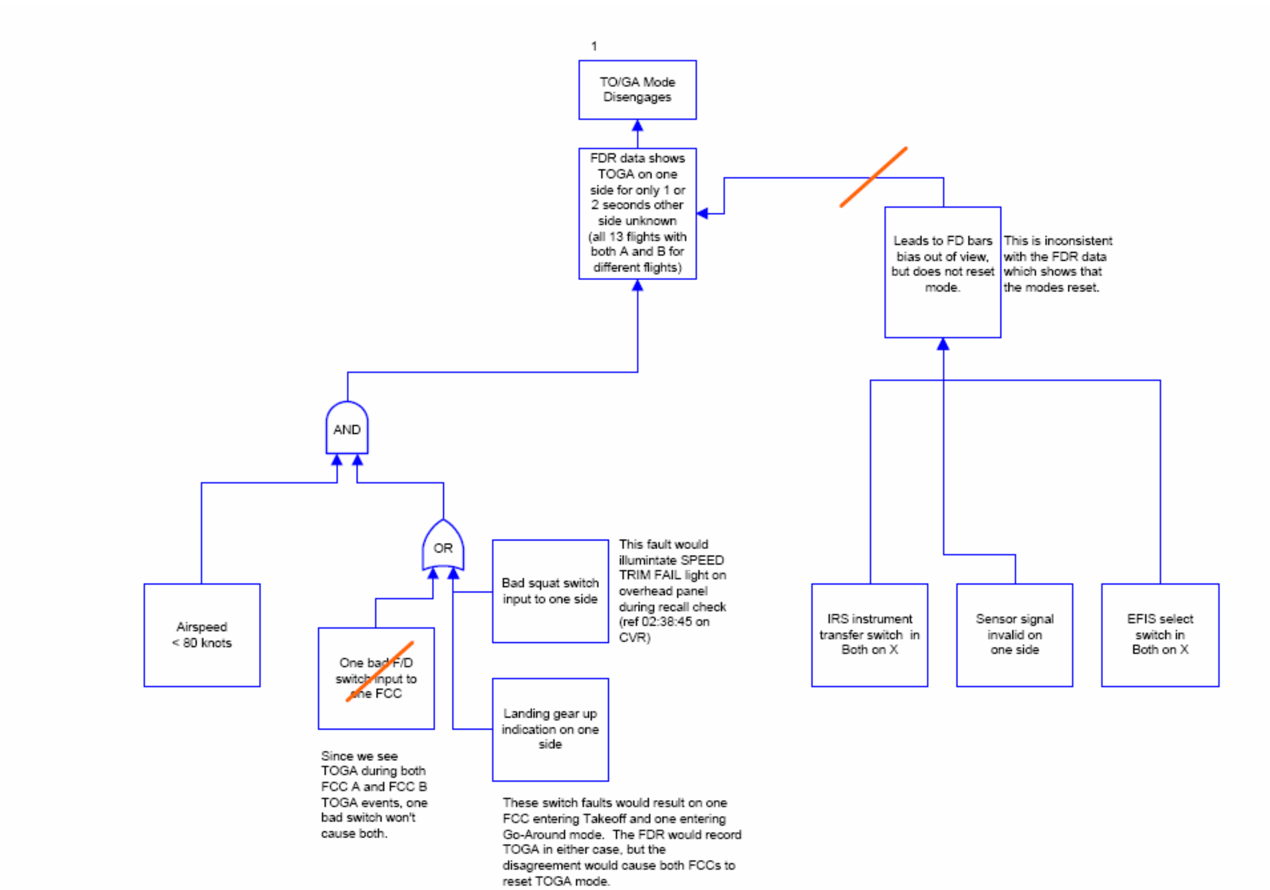


Fig 2.5.1.3.a TO/GA Mode Disengage Logic

[2] There is no corresponding entry in the aircraft's tech log. The chief pilot at Flash Air stated that he was aware of this fault on SU-ZCF and that work-around procedures were in place

- Since we see TOGA during both FCC A and FCC B TOGA events, one bad switch won't cause both. That makes the condition of “One bad F/D switch input to one FCC”.

- The condition of {(IRS instrument transfer switch in Both on X) + (Sensor signal invalid on one side) + (EFIS select switch in Both on X)} leads to FD bars bias out of view, but does not reset mode. This is inconsistent with the FDR data which shows that the modes reset.

- Regarding the” Landing gear up indication on one side”, the switch faults would result on one FCC entering Takeoff and one entering Go-Around mode. The FDR would record TOGA in either case, but the disagreement would cause both FCCs to reset TOGA mode.

- Regarding the “Bad squat switch input to one side”, this fault would illuminate SPEED TRIM FAIL light on overhead panel during recall check. (ref 02:38:45 on CVR)

Conclusion:

Based on the FDR data, the only possible causes for TOGA Mode Disengage are:

- Bad squat switch input to one side
- Landing gear up indication on one side.

There are no evidences that the TOGA mode disengagement has direct relation with the accident.
However, FDR data showed that this mode disengaged each time it was engaged.
No crew report for this anomaly was found.

2.5.2 Aileron Movement during Takeoff

2.5.2.1 FDR data related to the event:

- Before T.O., with both ailerons at same deflection (neutral position), the FDR showed a bias of about one degree up (0.9696 degree)
- During the airplane roll on ground and up to about 80 kts speed, the left aileron deflected upwards towards trailing edge up (TEU) direction (to a maximum value of about 3.2 degrees which is equivalent to about 2.2 degrees after considering the neutral bias). The right aileron deflected downwards towards trailing edge down (TED) direction (to a maximum value of about -1.2 degrees which is equivalent to about -2.2 degrees after considering the neutral bias).
- At about 80 knots (frame 92305), the ailerons were deflected to neutral. The FDR showed new neutral bias at this speed of about 2.24 degrees.
- After 80 Knots, the FDR showed ailerons deflections towards right bank command up to time frame 92334 (about 6 seconds after airborn). The right aileron reached a maximum deflection of about 8.5 degrees (about 6.3 degrees from neutral). The left aileron reached a maximum deflection of about -5.6 degrees (about -7.8 degrees from neutral).
- The wind condition was 280/08 at Take Off. The aircraft was taking off from runway 22R, with a relative wind direction of about 60 degrees. The cross wind component was about 6.9 kts blowing from the right side of the airplane.

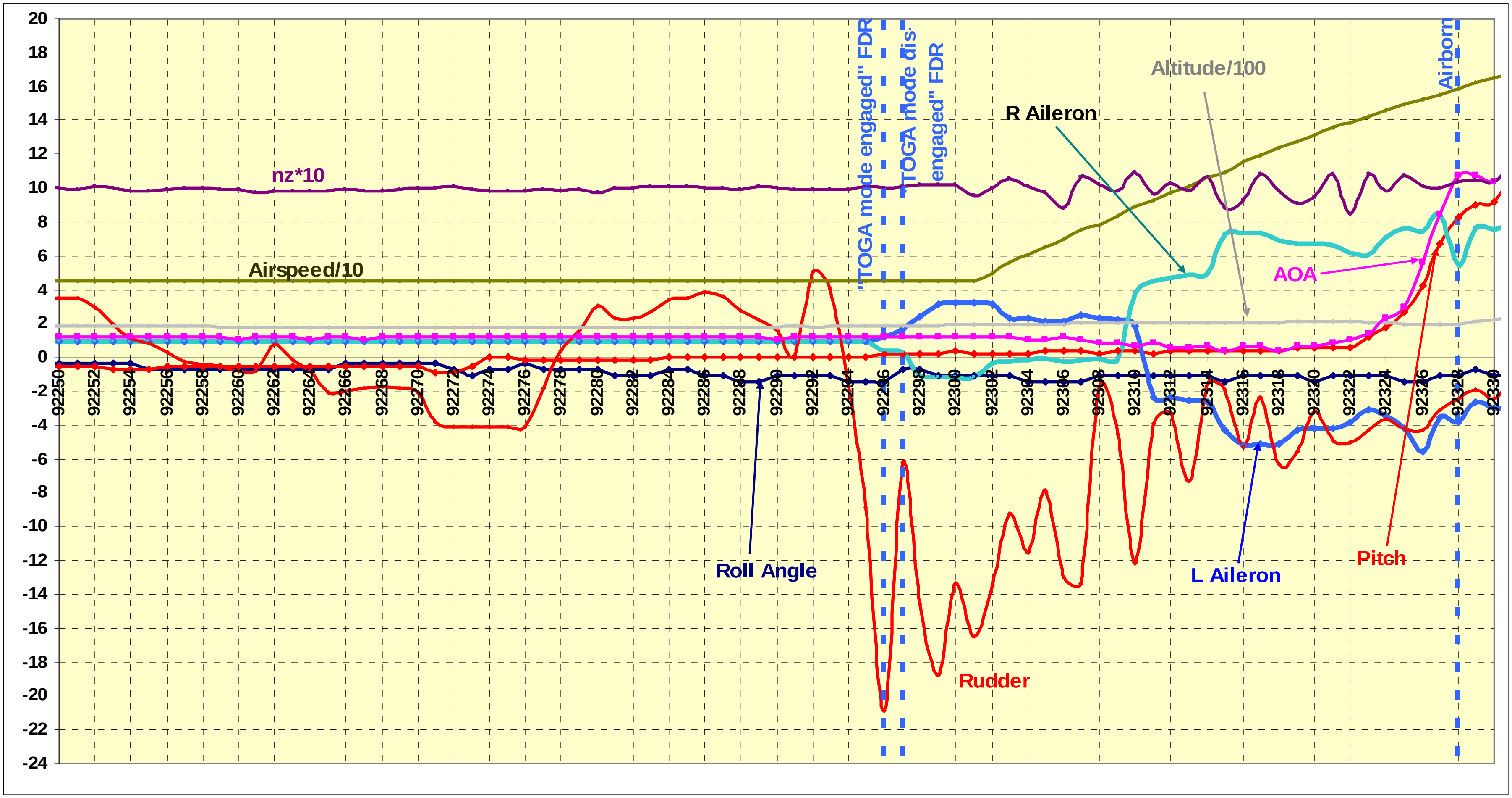


Figure 2.5.2.1a Aileron Movement during Takeoff event

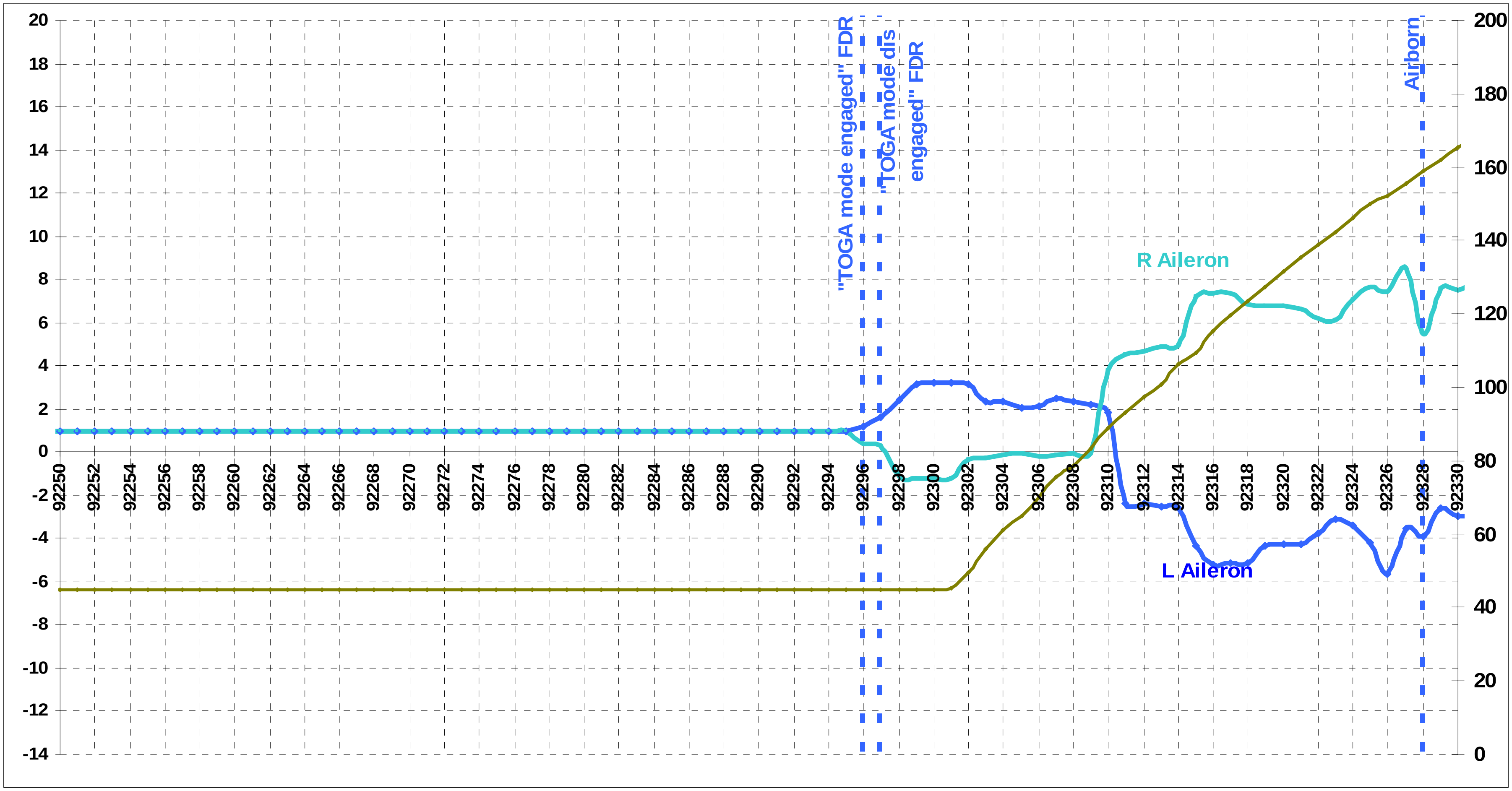


Figure 2.5.2.1b Aileron Movement during Takeoff event

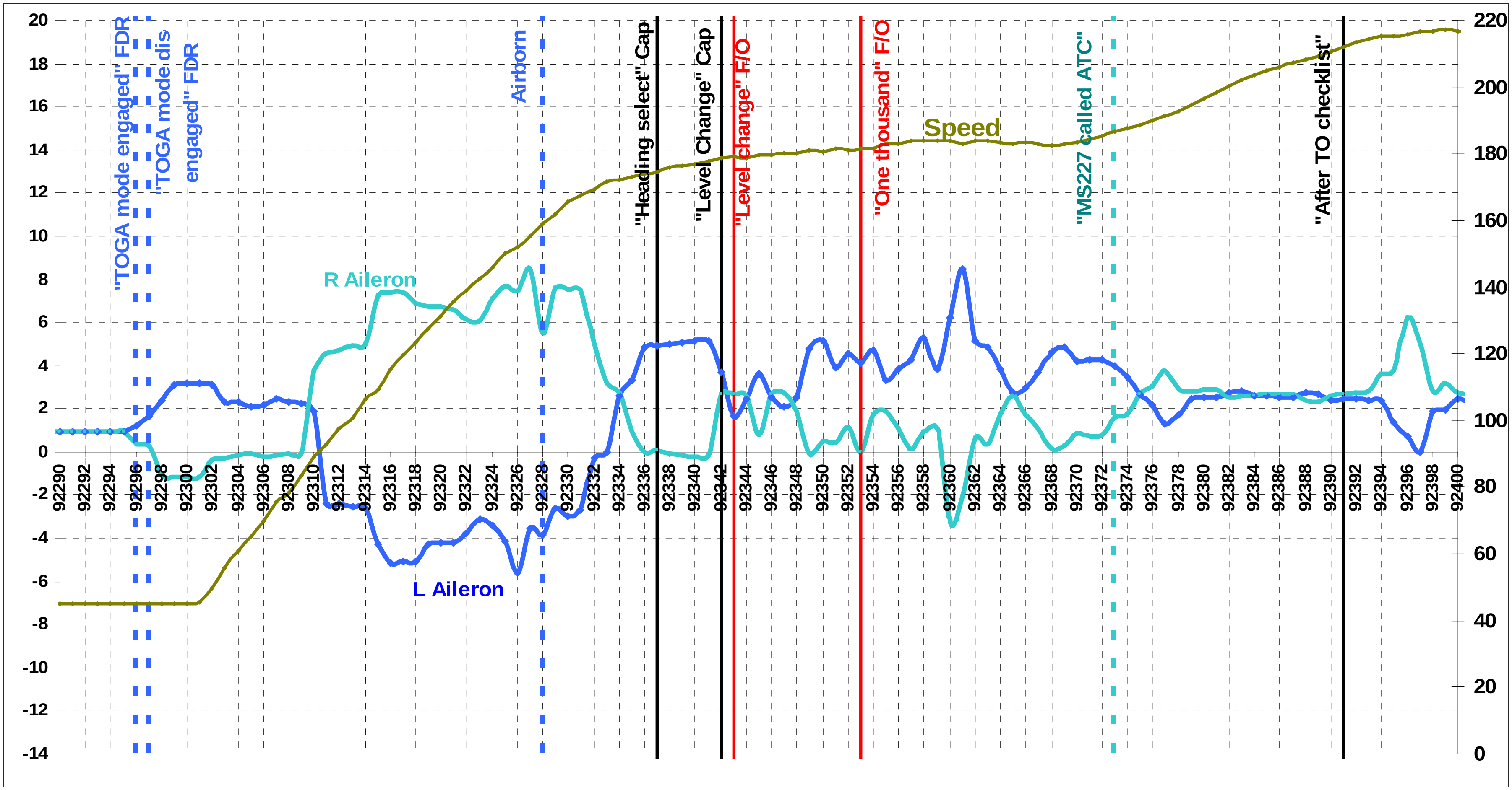


Figure 2.5.2.1c Aileron Movement during Takeoff event

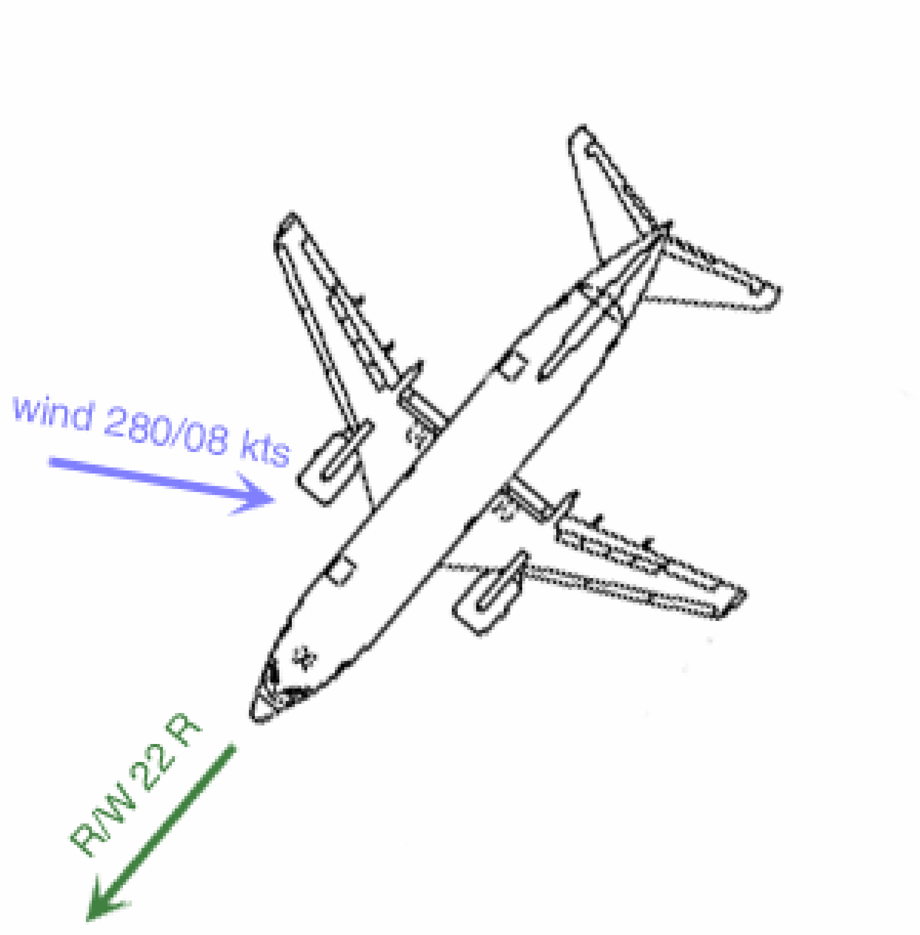


Figure 2.5.2.2 Wind direction during T.O

2.5.2.2 Aileron Float:

The left and right ailerons positions were related to the speed for the last 25 flying hours (for both PQ294 and PQ481 airplanes). Results are shown in the following figures[1]:

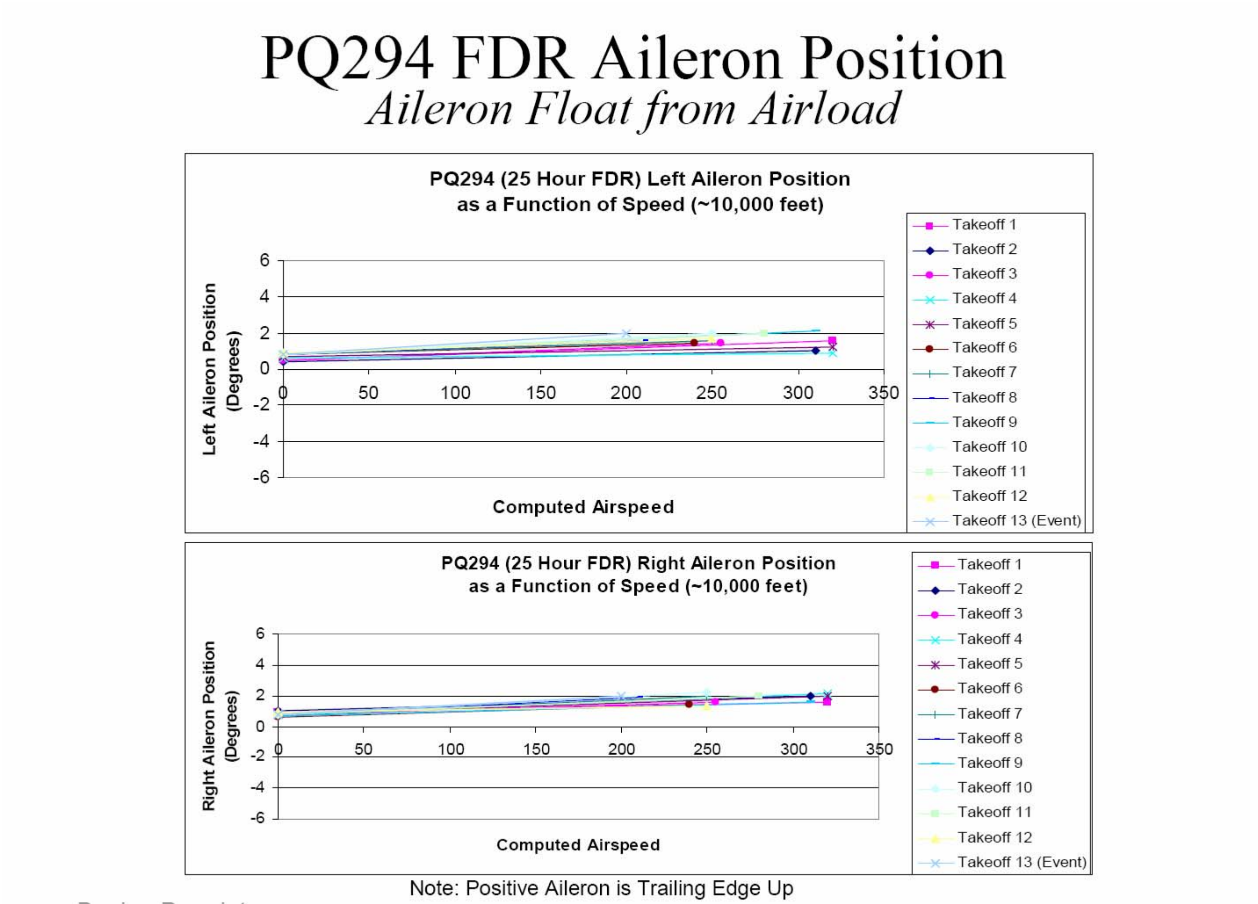


Figure 2.5.2.3a Aileron float from Airload (PQ294)

[1] Study presented by Boeing during March 2004 meeting in Cairo

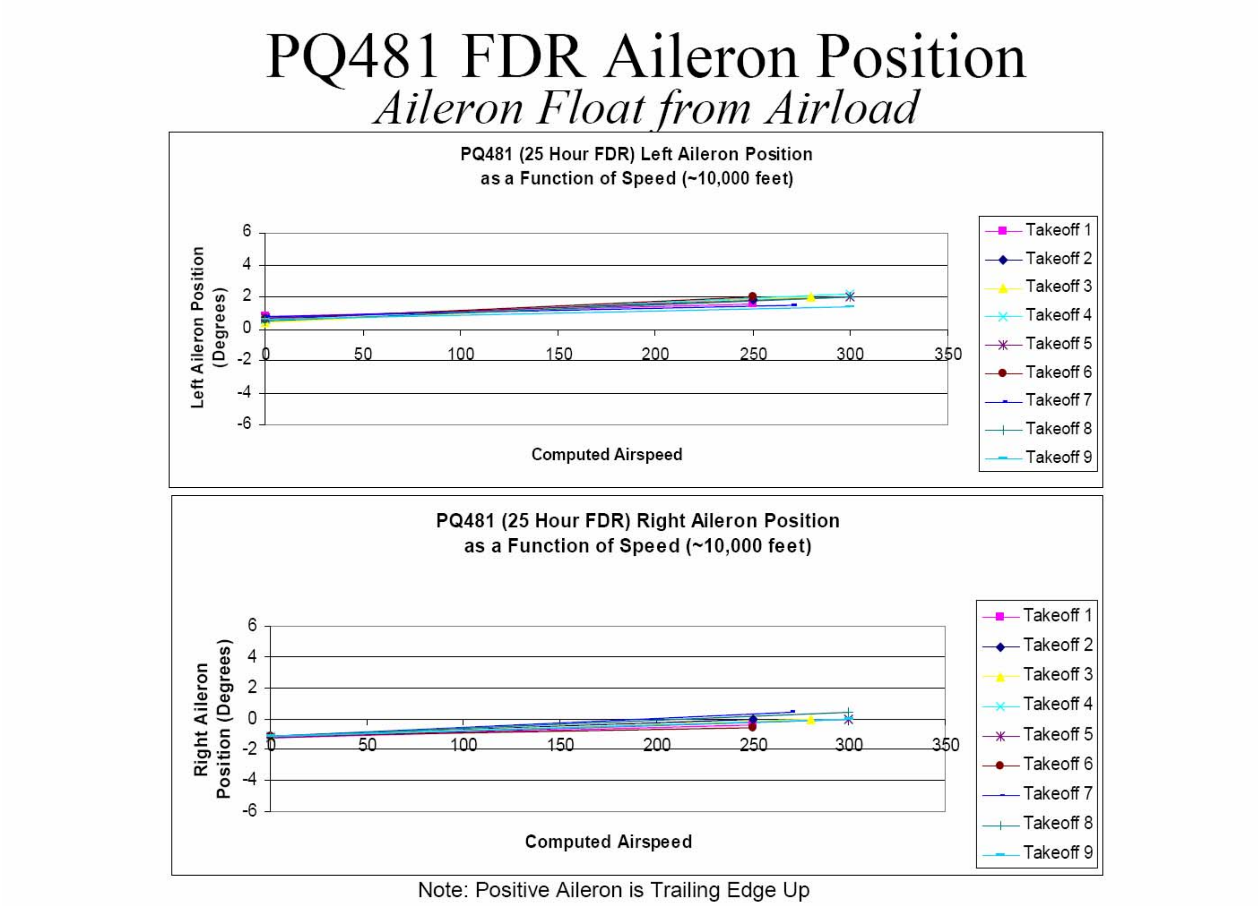


Figure 2.5.2.3b Aileron float from Airload (PQ481)

As shown from the above figures, the ailerons blow up as result of increasing speed is not exactly the same for all Take Off's. The aileron blow up increases with increasing speed.

Conclusion:

- Aileron movement direction during Takeoff is consistent with the wind condition existing during the Takeoff.
- Aileron bias change could be related to change in airplane speed.

Based on the FDR available date, there is no evidence that the aileron movement during Takeoff could gave direct relation with the accident.

2.5.3 FD Modes (Pitch & Roll) Re-Engagement

Based on the CVR and FDR data:

- After takeoff and at 02:42:43 the captain called for HDG SEL "Four Hundred Heading select".
- At 02:42:44 First officer (F/O) confirmed "Four Hundred Heading select sir"
- At time 2:42:47, FDR data indicates Heading Select mode engaged (Radio Altitude indicated 371 feet AGL) (Frame 92341)
  (Setting "HDG SEL" mode would restore the FD roll command bar).

- At 42:48 Captain called for Level Change
- At 02:42:49 First officer confirmed "Level Change, MCP speed, N1 Armed sir"
- At time 2:42:50, FDR data indicates Level Change mode engaged (Frame 92344)
  (Setting "Level Change" mode would restore the FD pitch command bar).

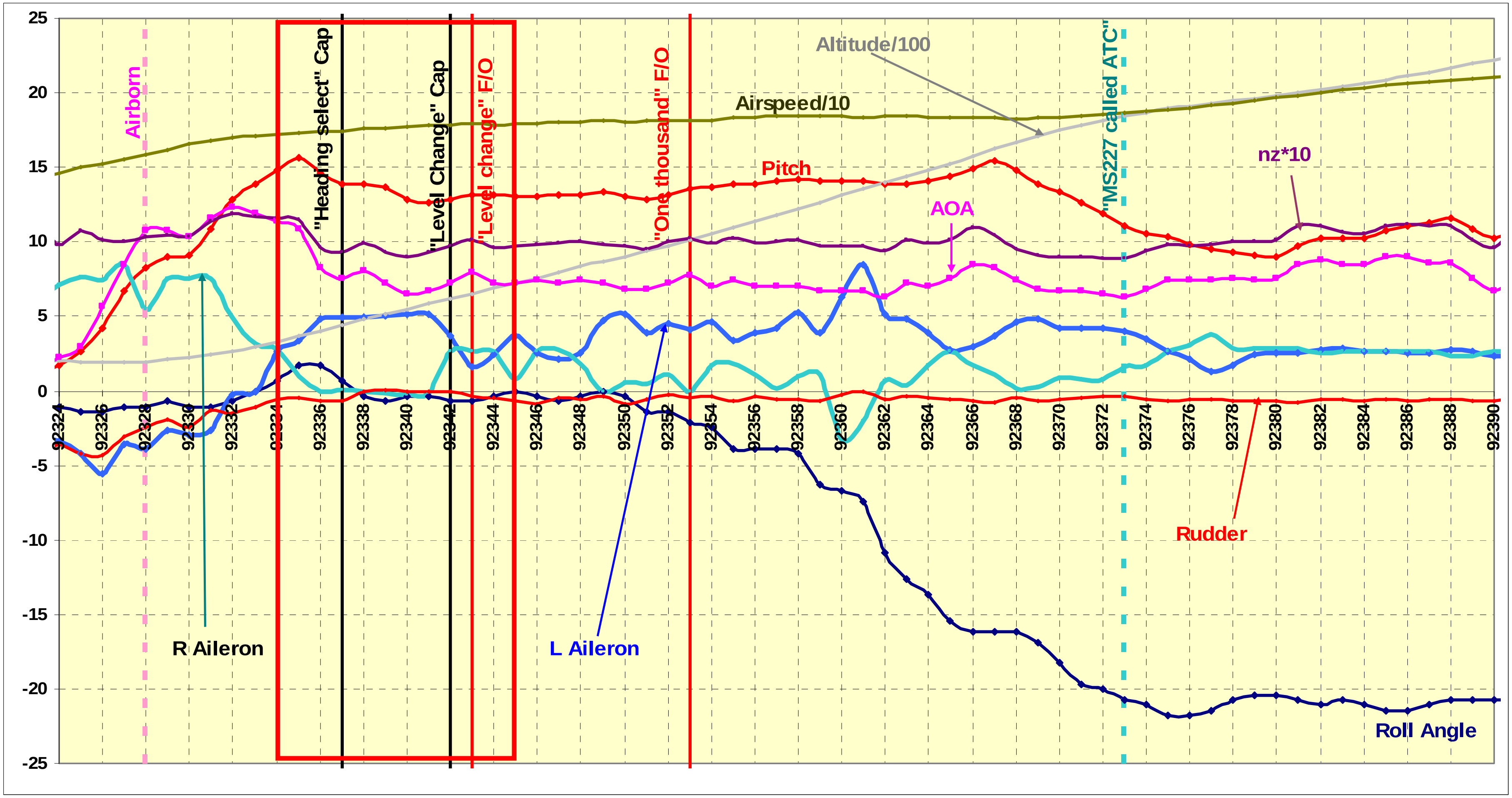


Figure 2.5.3.1 FD Modes (Pitch & Roll) Re-Engagement event

Conclusion:

Setting “HDG SEL” and “Level Change” modes is normal and expected to restore the FD roll and pitch bars. These settings have no direct relations with the accident.

2.5.4 Roll Left and Left Turn Begun

The left turn is part of the planned departure pattern.

The crew received ATC clearance for a “left turn to intercept radial three zero six”. This radial forms the airway to Cairo and involves a left turn of 274° from runway 22. They briefed the departure and began the left turn as planned.

Note: Though not published, a 270° turn is the customary night-time departure patterns from SSH and would have been familiar to the crew. The direction of turn (left or right) depends upon the runway used, but should be over the Red Sea. In fact, the FDR records that the accident crew successfully flew the mirror image pattern about 24 hours previously (right turn of 266° from runway 4).

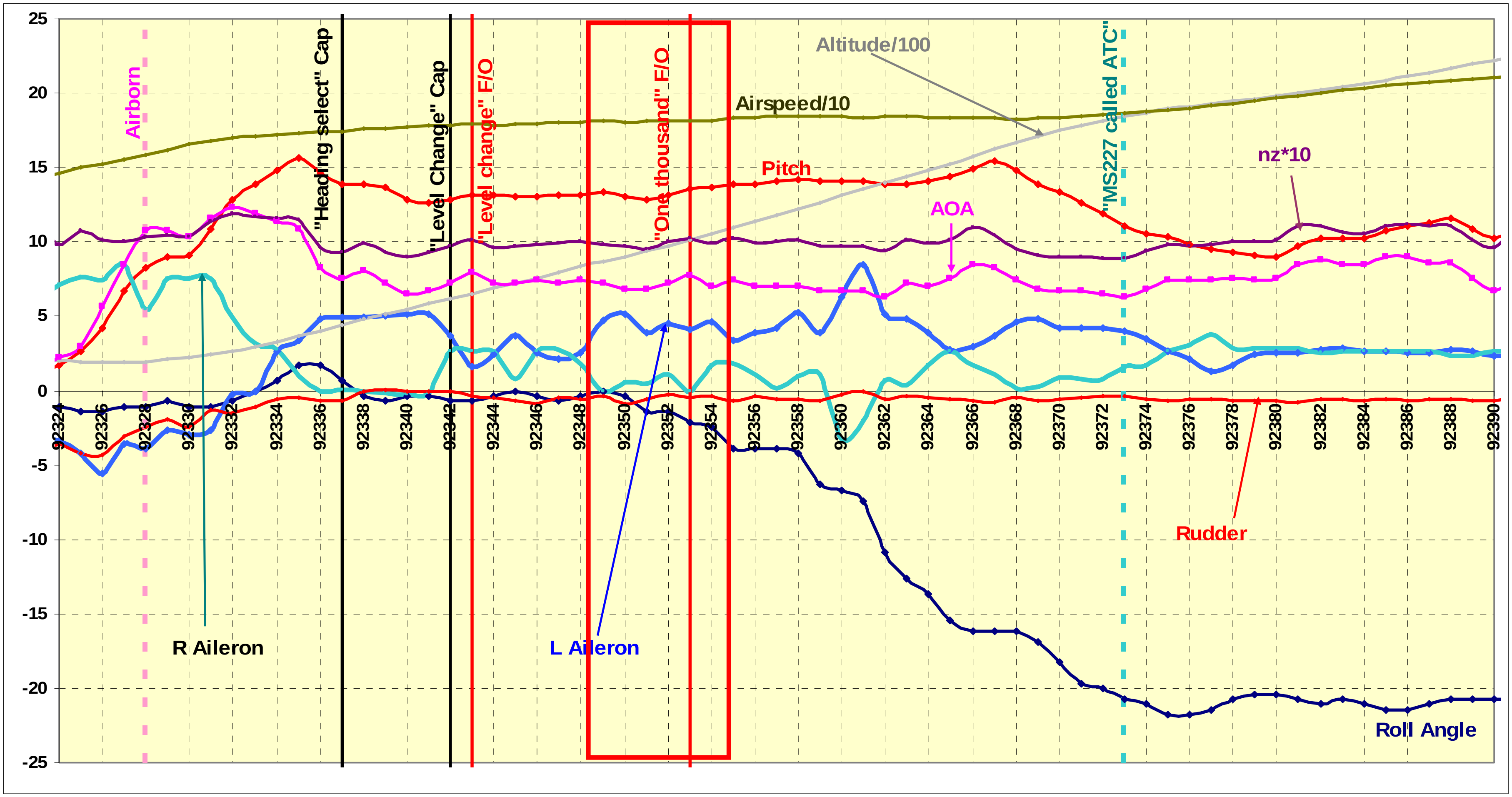


Figure 2.5.4.1 Roll Left and Left Turn Begun event

Conclusion:

The Roll Left and the beginning of Left Turn are normal and expected to intercept and follow the Radial 306 to Cairo. These movements have no direct relation with the accident.

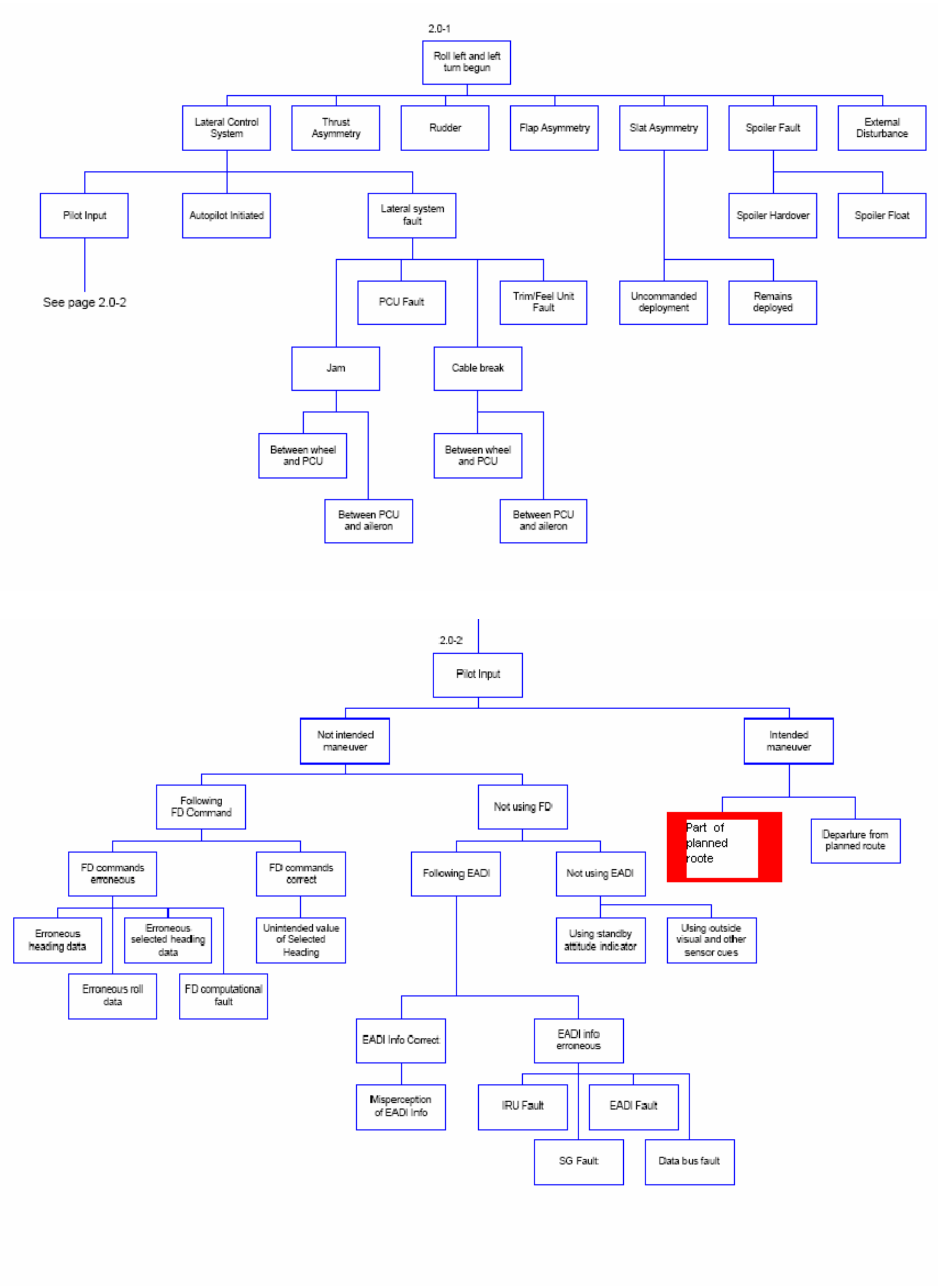


Figure 2.5.4.2 Roll Left and Left Turn Begun analysis

2.5.5 Roll back towards wing level

Based on the FDR data and at almost time frame 92419 second, the airplane left turn stopped and the wings became in level condition

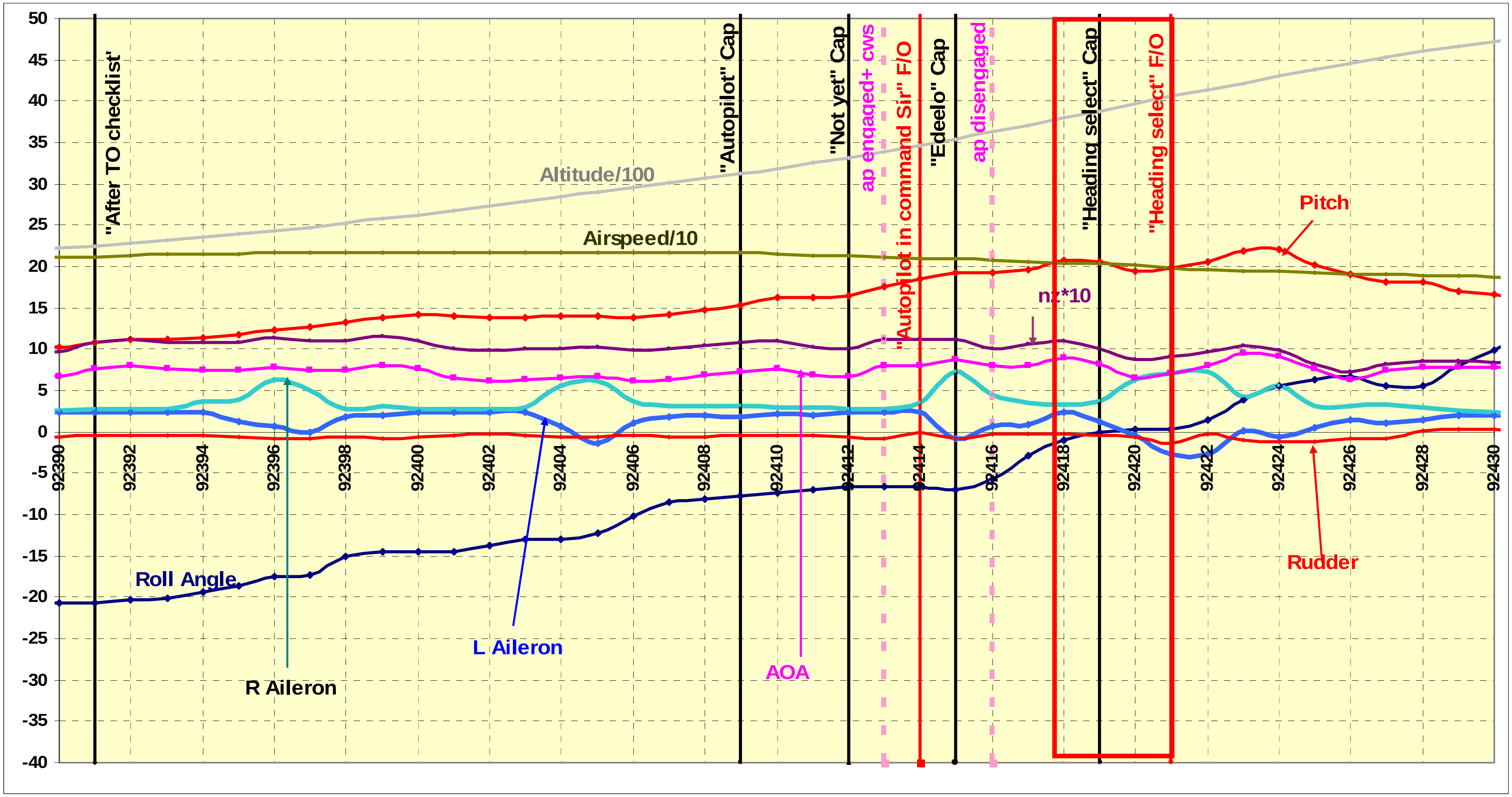


Figure 2.5.5.1 Roll back towards wing level event

2.5.5.1 Conditions which could lead to this event

A. NA

B- Flaps assymetry:

The FDR did not show evidences of flap asymmetry. Based on these information, there is no evidence of flap asymmetry existing at the time of the event and consequently this condition could be ruled out

C- Slats assymetry:

C.1 Uncommanded Deployment

Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

C.2 Remains Deployed (SLAT FULL DEPLOYED)

Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

D- Thrust assymetry

With reference to section “2.3.6. Power plants”, it is shown that all the engines parameters were recorded in the FDR. However, some parameters data were not reliable (e.g. L engine N1). The other engines parameters are reliable including the N2 for both engines.. Based on these information, there is no evidence of thrust assymetry existed at the time of the event and consequently this condition could be ruled out

E- External Disturbance

This condition could be ruled out based on FDR data, M- Cab Simulator Match to FDR and meteorogical data

F- Anomalies with the lateral control system

See Appendix 2-1 lateral control analysis, and section 2.5.13 Right roll continues to overbank with ailerons activities, Lateral control system

G- Pilot input.

This condition could not ruled out

2.5.5.2 M Cab results related to Simulated Failures (Spoilers, LE Slats)

Simulated failures:

1. Right outboard flight spoilers (#7) Hardover simulation (hardover starts at 92391)
2. Left outboard flight spoilers (#2) Hardover simulation (hardover starts at 92391)

3. Right outboard flight spoilers (#7) Float simulation (floats starts at 92391)
4. Left outboard flight spoilers (#2) Float simulation (floats starts at 92391)

5. Critical right wing leading edge slat # 6 extends
6. Critical left wing leading edge slat # 1 extends

It is to be noted that the results of the M-Cab tests as indicated in the appendix figures, show that the scenarios resulted from all the above mentioned simulated failures are not consistent with the accident scenario. Therefore, these simulated failures could be ruled out.

2.5.5.3 Roll Left and beginning of Left Turn possible causes:

After completing the process of elimination of the unlikely possibilities, the following conditions could be considered as possible causes leading to this event:

1- Widening Departure Pattern (intentional control action)

This possible cause is supported by the following evidences:

- Chief pilot reports some crews choose to widen their departure pattern by squaring turn at approximately 90° to runway heading. The wings level heading, 140°, is 80° from the runway heading.
- Although there was no specific briefing about widening pattern, the flight path is consistent with information provided by the Ex-Chief Pilot of Flash Airline concerning usual pattern
- The aircraft remained near heading 140 for 9 seconds. Roll rate decreases as aircraft nears 140.
- The PF (captain) may have wanted to ensure that he did not violate the local VOR altitude crossing practice.
- The previous day's departure from SSH included a 270 turn to right with altitude deviation

However, the following should be noted:

- The same crew made a similar departure about 24 hours previously, at a heavier weight without widening their departure and with altitude deviation.
- There is no discussion about this maneuver recorded on the CVR.

2- Mistaken understanding of "Initially 140" (intentional)

- ATC clearance: "Destination Cairo as filed, climb initially flight level one four zero", F/O read back "destination Cairo via flight plan route one four zero". Captain later asked for confirmation about "Initially 140" from F/O and for F/O to confirm with ATC. After initial clearance, neither ATC nor F/O specified whether "140" refers to a heading or altitude. Airplane rolls wings level on exactly 140.
- It has to be noticed that the crew never briefed the departure as it is usually done (headings, sets, displays,).Therefore all the dialogues between the Captain and the F/O before the turn is about "140". From 2:41:19 to 2:41:40 it is clear that the Captain's mind is focused on a 140° Heading: 2:41:19 F/O "left turn to establish 306", 2:41:29 Captain "initially 140". This match with what said Flash ex-Chief pilot in his last statement about widening pattern. This might rule out "mistaken initial 140 heading interpretation".

-

However, the following evidences do not support this possibility assumption:

- No request from captain to set selected heading to 140.
- Did not ask for clarification of "Heading' clearance.

- “Initially” phrase refers to altitude, not heading.
- “14000” set in altitude window immediately after ATC clearance and was in the window during subsequent discussion and confirmation with ATC.

3- To level wings prior to engaging autopilot (intentionally)

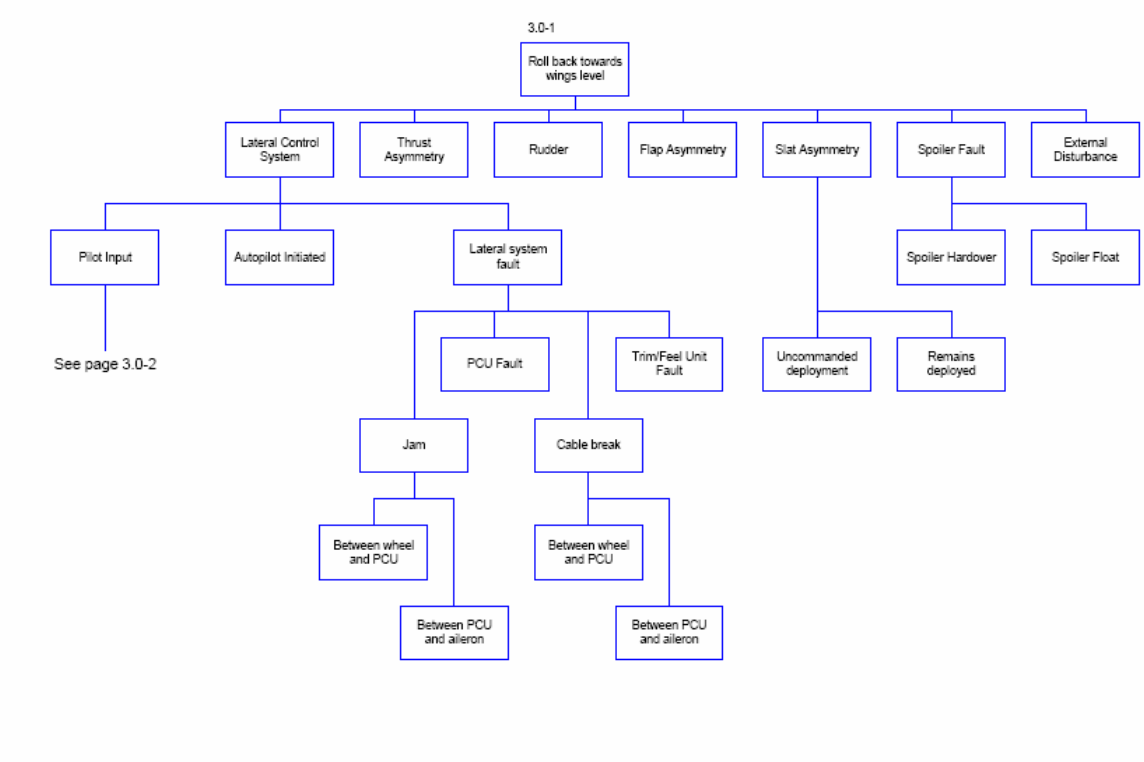
On FDR previous flight, the same crew did not engage the AP until wings level at approximately 9000 ft following completion of a series of turns after takeoff
However, On FDR flight, the crew engaged the autopilot in the middle of a 270° turn at a bank angle of 20 to 25°.

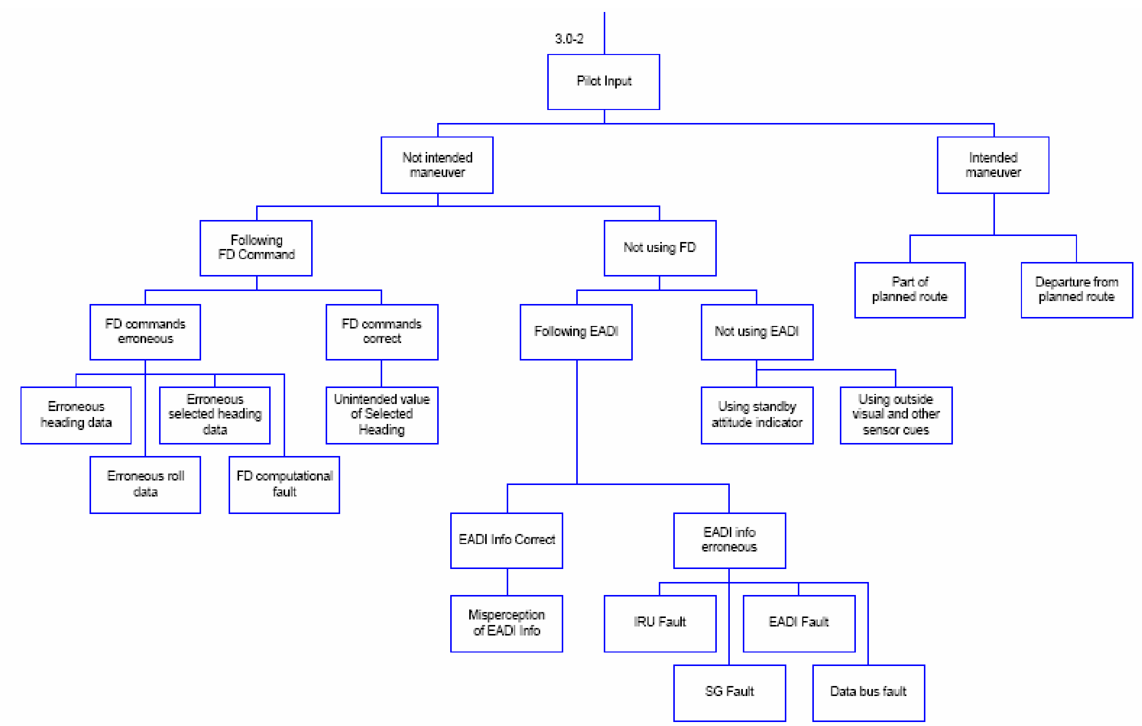
4- Pilot loses awareness of heading or bank (unintentional)

Roll out coincident with passing over coastline and resulting loss of outside visual references. Pitch begins to deviated from expected value. Misleading vestibular cues were present.
However, attitude information available on displays to 3 flight deck occupants.

Conclusion:

The investigation could not determine a higher possibility to any of the above findings based on the given data.


3.0-1
Roll back towards wings level
Lateral Control System
Thrust Asymmetry
Rudder
Flap Asymmetry
Slat Asymmetry
Spoiler Fault
External Disturbance
Pilot Input
Autopilot Initiated
Lateral system fault
Spoiler Hardover
Spoiler Float
See page 3.0-2
PCU Fault
Trim/Feel Unit Fault
Uncommanded deployment
Remains deployed
Jam
Cable break
Between wheel and PCU
Between wheel and PCU
Between PCU and aileron
Between PCU and aileron

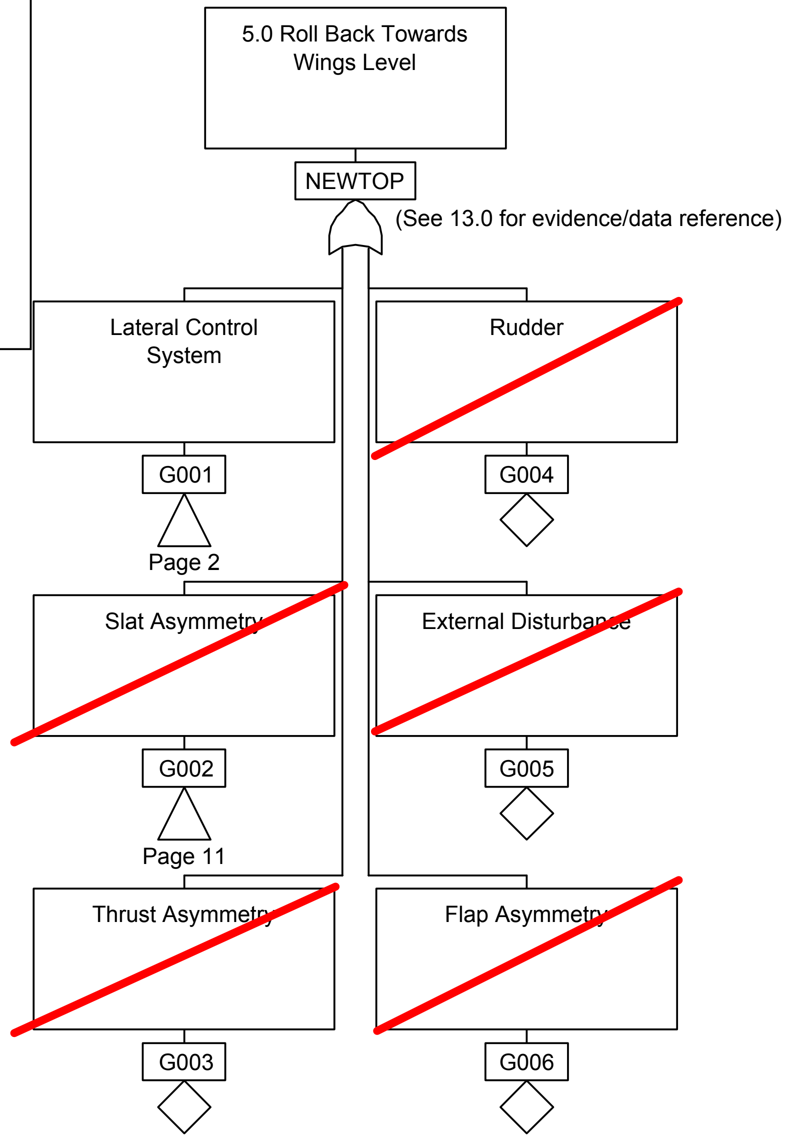

3.0-2
Pilot Input
Not intended maneuver
Intended maneuver
Following FD Command
Not using FD
Part of planned route
Departure from planned route
FD commands erroneous
FD commands correct
Following EADI
Not using EADI
Erroneous heading data
Erroneous selected heading data
Unintended value of Selected Heading
Using standby attitude indicator
Using outside visual and other sensor cues
Erroneous roll data
FD computational fault
EADI Info Correct
EADI info erroneous
Misperception of EADI Info
IRU Fault
EADI Fault
SG Fault
Data bus fault

Legend:

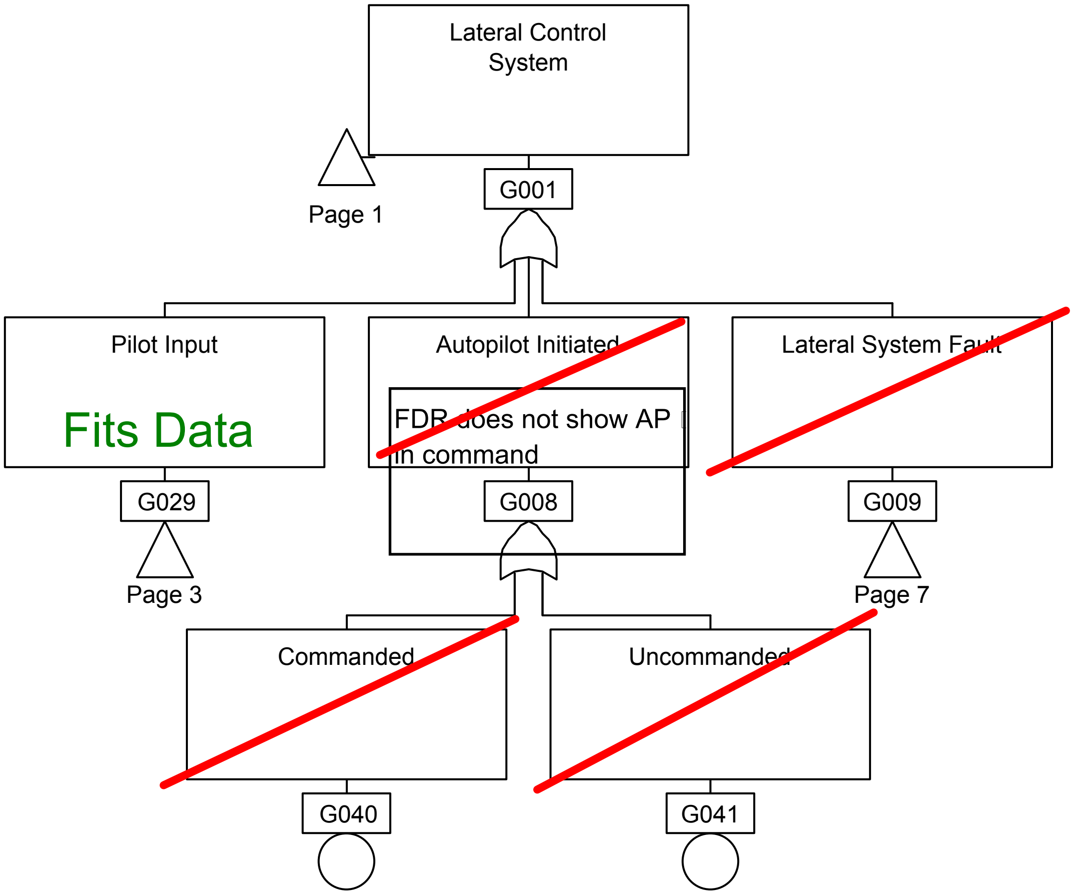
◇ Sufficient Data Collected at This Point

◎ May Need More Data

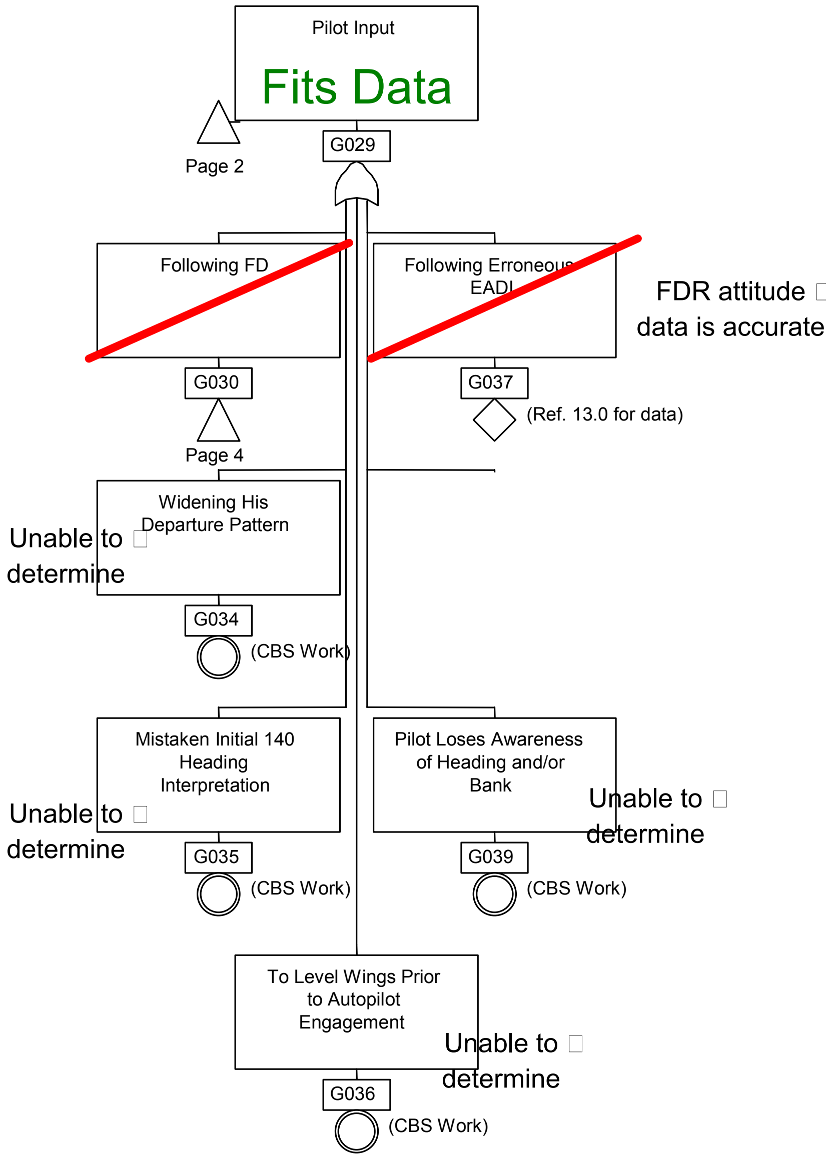
○ Not Eval'd for Data Needs

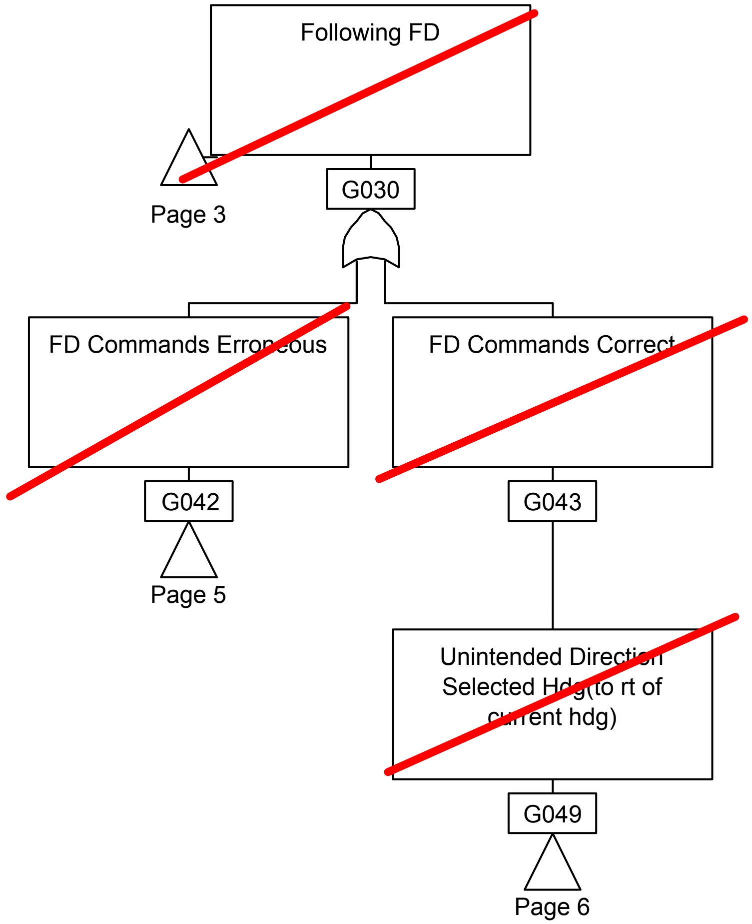


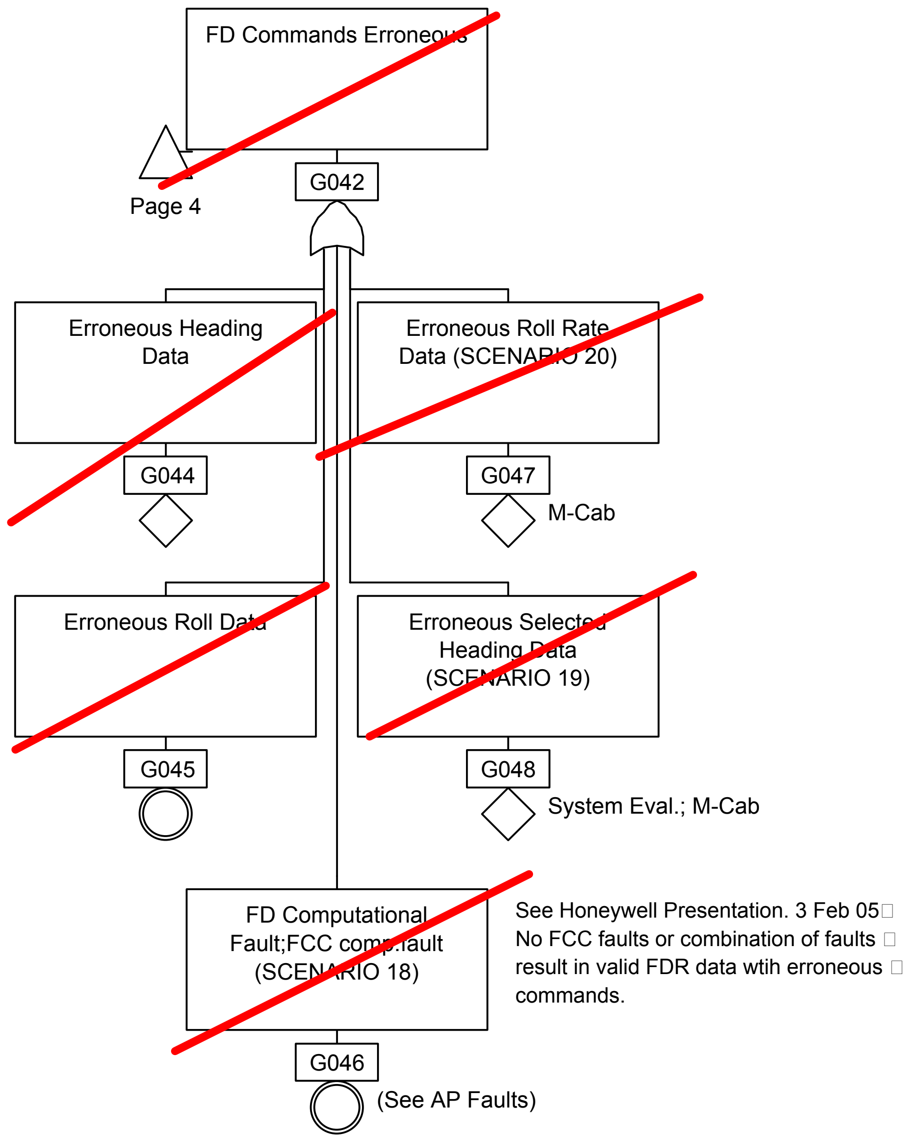
Updated: 10/1/04 (Seattle)

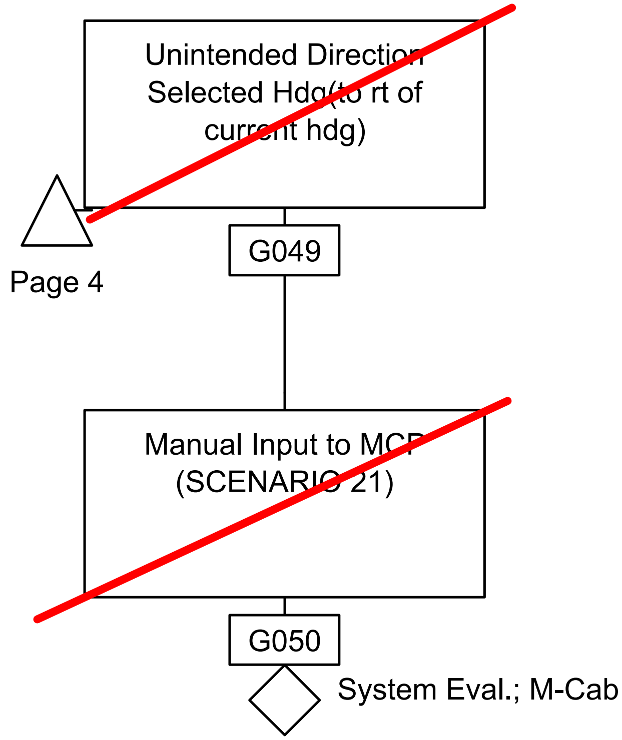


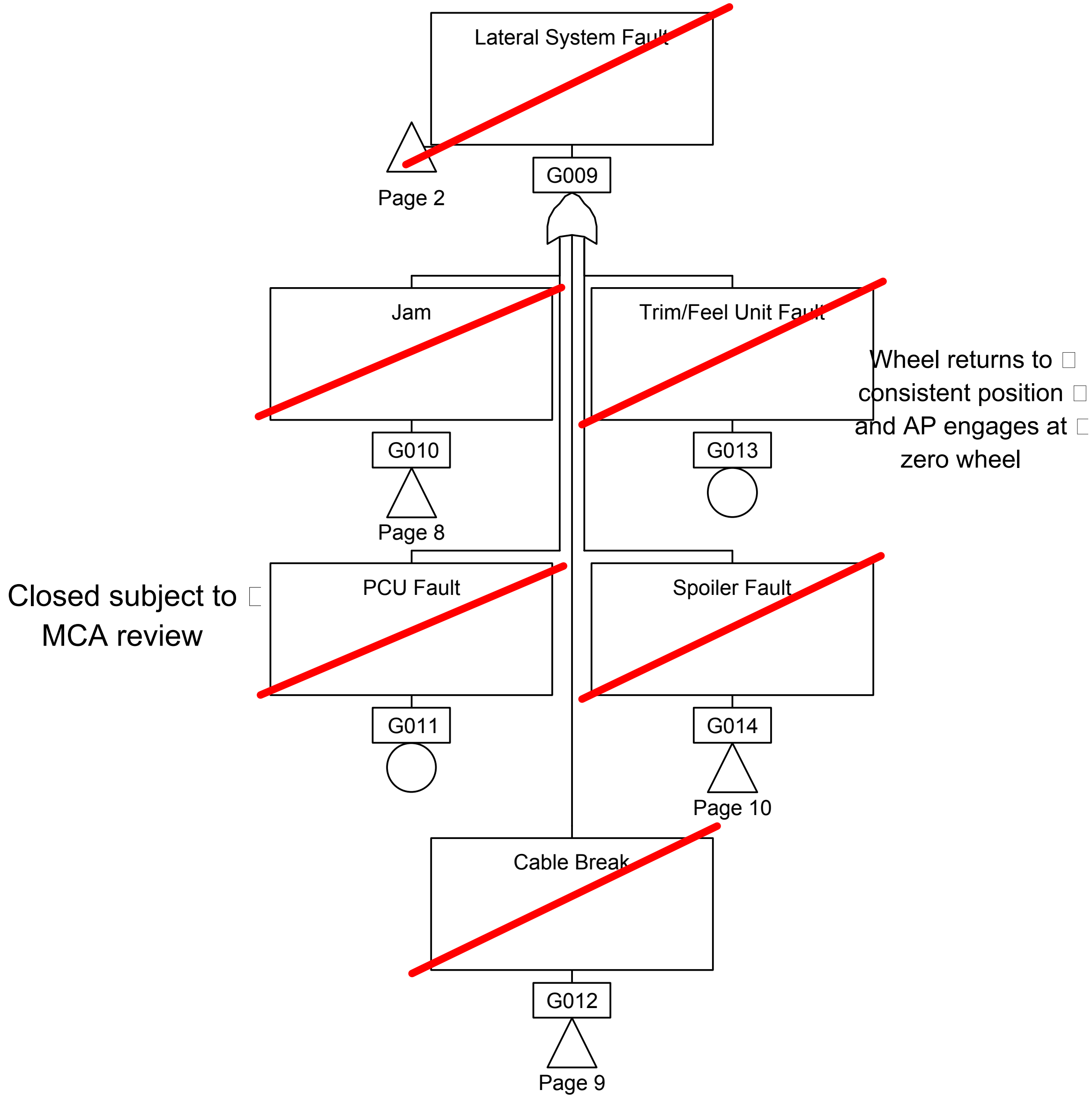
Lateral Control System
Page 1
G001
Pilot Input
Fits Data
G029
Page 3
Autopilot Initiated
FDR does not show AP in command
G008
Lateral System Fault
G009
Page 7
Commanded
G040
Uncommanded
G041

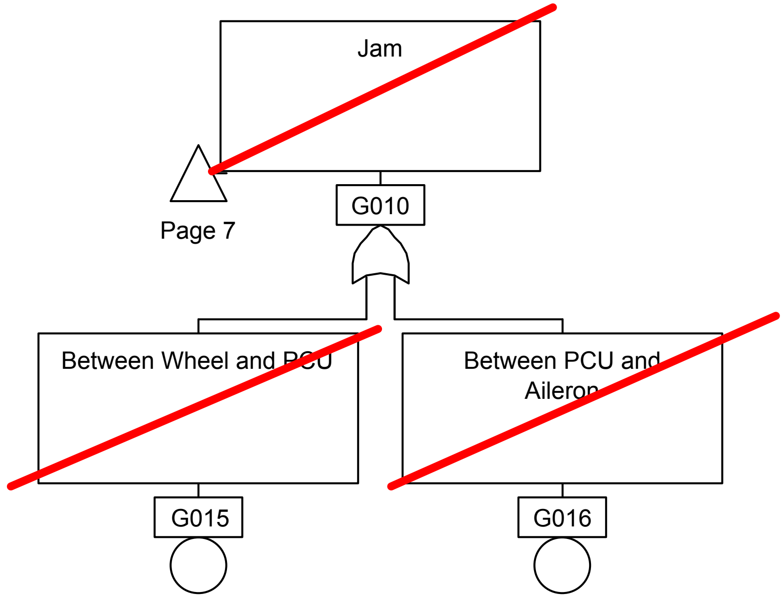

Pilot Input
Fits Data
Page 2
G029
Following FD
G030
Page 4
Following Erroneous EADI
G037
FDR attitude data is accurate
(Ref. 13.0 for data)
Widening His Departure Pattern
Unable to determine
G034
(CBS Work)
Mistaken Initial 140 Heading Interpretation
Unable to determine
G035
(CBS Work)
Pilot Loses Awareness of Heading and/or Bank
Unable to determine
G039
(CBS Work)
To Level Wings Prior to Autopilot Engagement
Unable to determine
G036
(CBS Work)

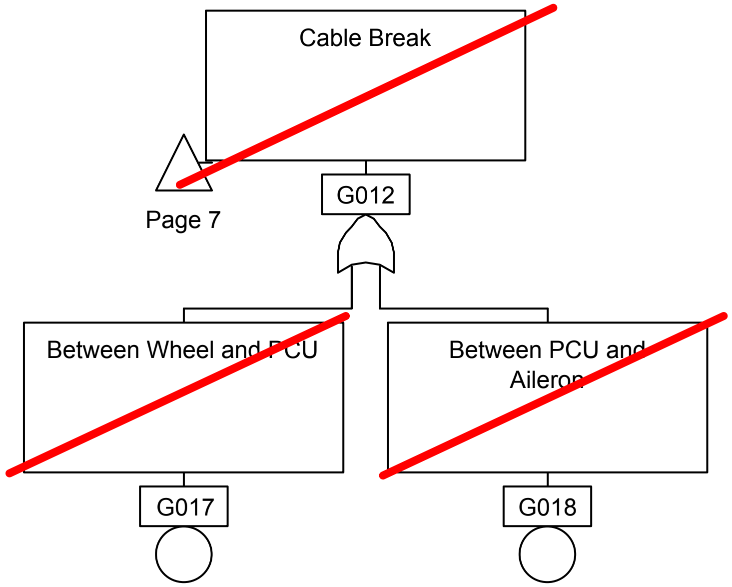

Following FD
Page 3
G030
FD Commands Erroneous
FD Commands Correct
G042
G043
Page 5
Unintended Direction Selected Hdg(to rt of current hdg)
G049
Page 6

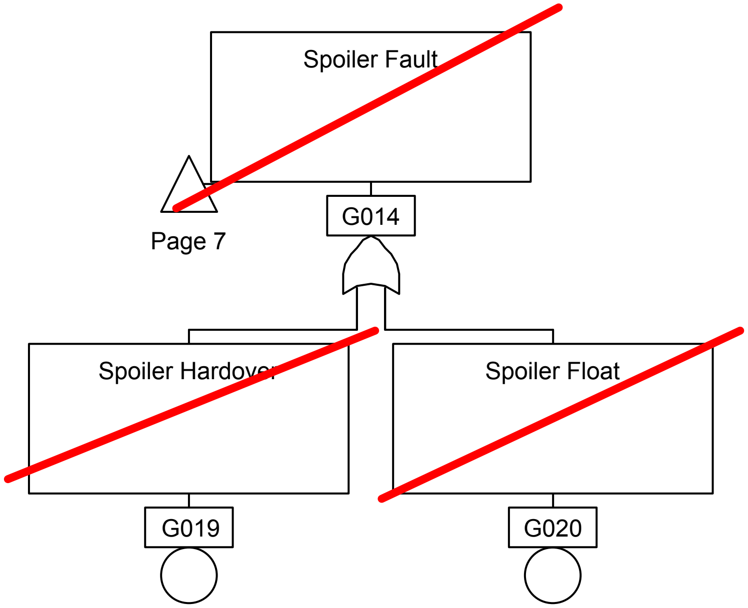

FD Commands Erroneous
Page 4
G042
Erroneous Heading Data
G044
Erroneous Roll Rate Data (SCENARIO 20)
G047
M-Cab
Erroneous Roll Data
G045
Erroneous Selected Heading Data (SCENARIO 19)
G048
System Eval.; M-Cab
FD Computational Fault;FCC comp.fault (SCENARIO 18)
See Honeywell Presentation. 3 Feb 05
No FCC faults or combination of faults
result in valid FDR data wtih erroneous
commands.
G046
(See AP Faults)

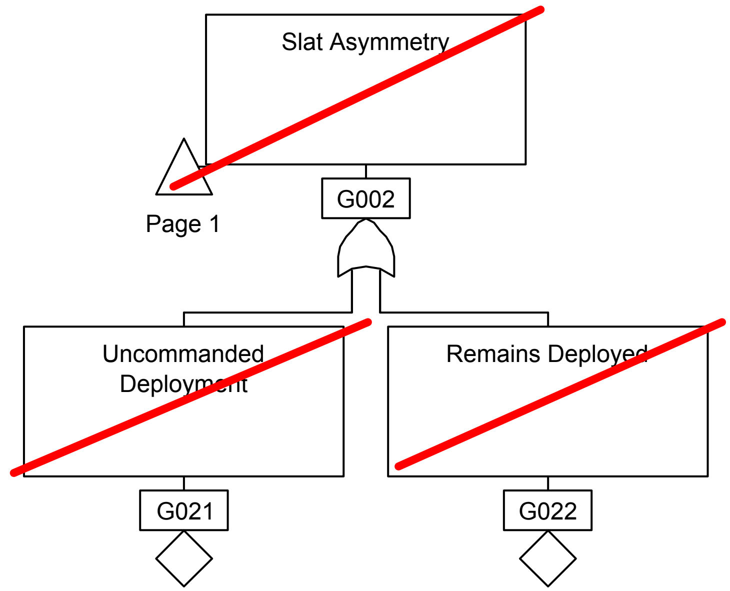

Unintended Direction Selected Hdg(to rt of current hdg)
Page 4
G049
Manual Input to MCP (SCENARIO 21)
G050
System Eval.; M-Cab


Lateral System Fault
Page 2
G009
Jam
Trim/Feel Unit Fault
Wheel returns to consistent position and AP engages at zero wheel
G010
G013
Page 8
Closed subject to MCA review
PCU Fault
Spoiler Fault
G011
G014
Page 10
Cable Break
G012
Page 9


Jam
Page 7
G010
Between Wheel and PCU
Between PCU and Aileron
G015
G016


Cable Break
Page 7
G012
Between Wheel and PCU
Between PCU and Aileron
G017
G018


Spoiler Fault
Page 7
G014
Spoiler Hardover
Spoiler Float
G019
G020


Slat Asymmetry
Page 1
G002
Uncommanded Deployment
Remains Deployed
G021
G022

2.5.6 Pitch up and airspeed decay

Based on the FDR data the speed reached 217 Kt at time frame 92405 (seconds), but the speed decreased to 184.5 Kts at 92437.

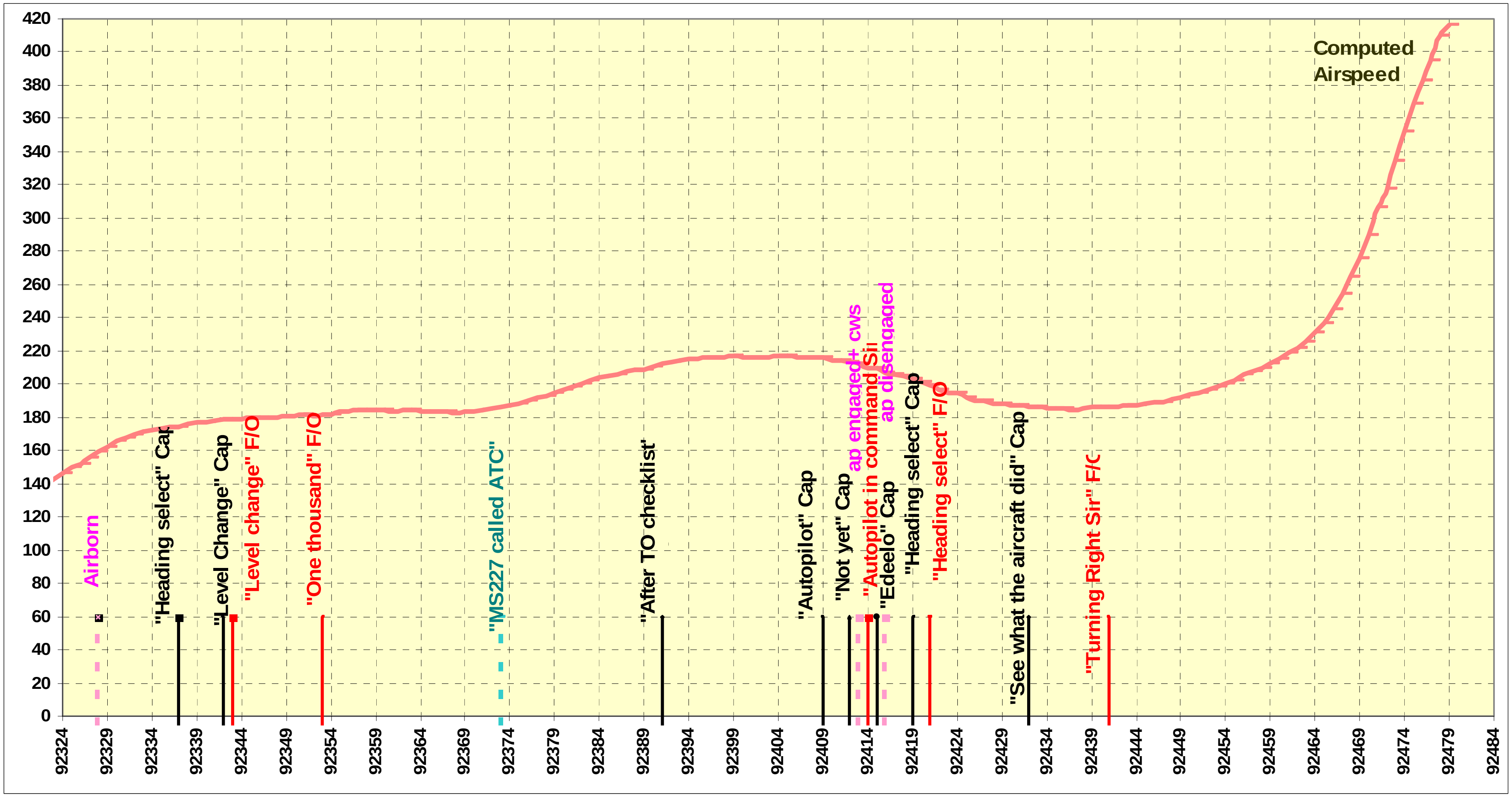


Figure 2.5.6.1 Pitch up and airspeed decay

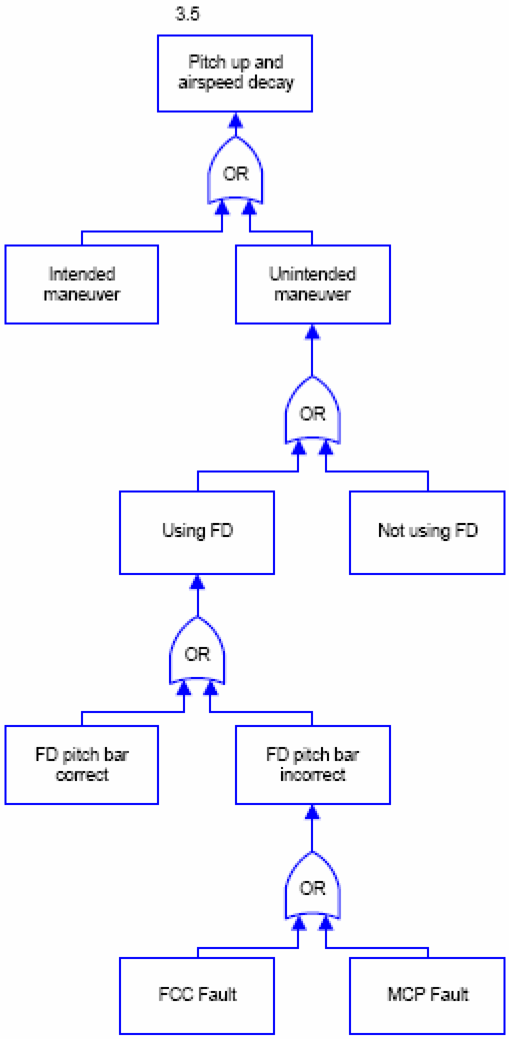
Pitch up and airspeed decay analysis:

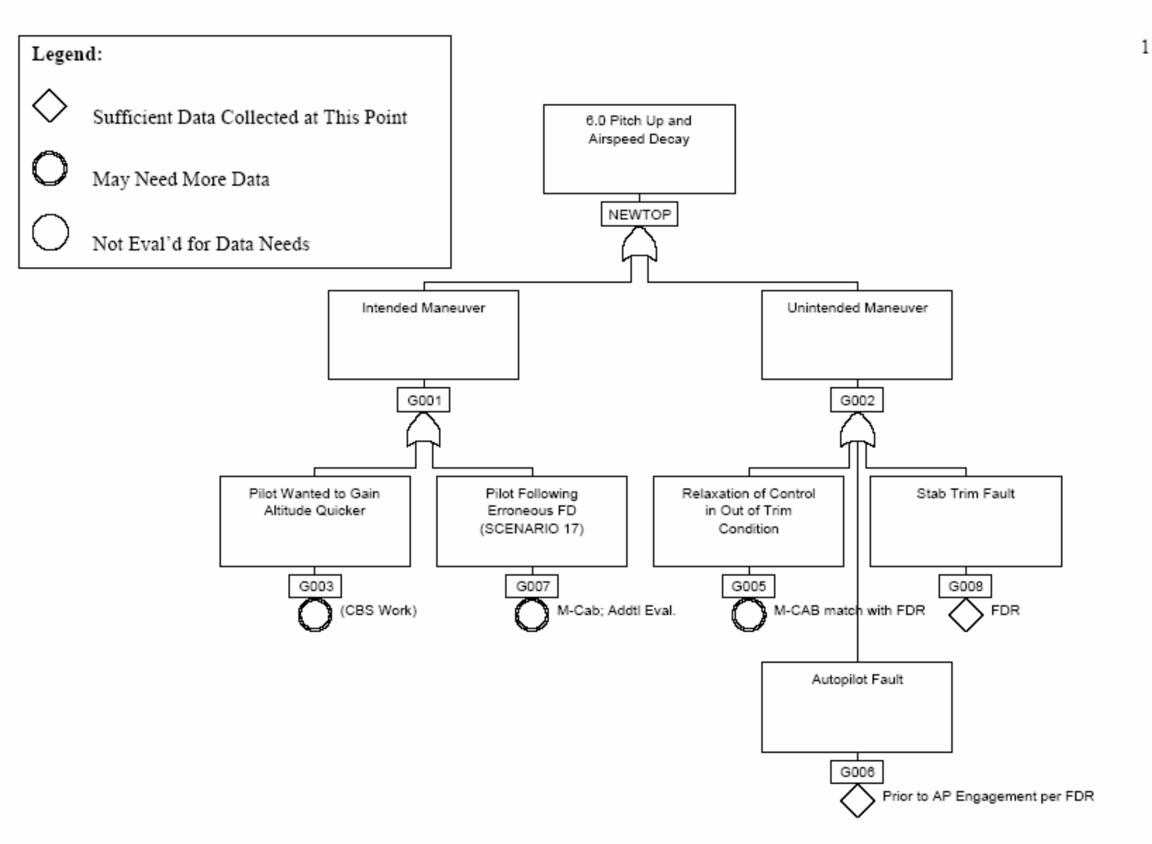
The possible conditions which might lead to this event are shown in the following:

1. Pilot Wanted to Gain Altitude Quicker (Intended Maneuver)
   This possibility may be supported by the fact that the airplane should intercept the VOR radial at a minimum of 11,000 ft
2. Pilot Following Erroneous FD (intended)
   There are not enough data to rule in or rule out this probability
3. Relaxation of Control in Out of Trim Condition (Unintended Maneuver)
   The results from the M-CAB tests match with FDR
4. Autopilot Fault (Unintended Maneuver)
   This condition might be ruled out. This event started prior to AP Engagement (based on FDR data)
5. Stab Trim Fault (Unintended Maneuver)
   This condition might be ruled out. Based on FDR data, the stabilizer did not show abnormal behavior throughout the flight.
6. Pilot pulling on the control column (unintentional)

Conclusion:

With the exclusion of the ruled out (conditions 4 and 5), the investigation could not determine a higher possibility to any of the remaining conditions (conditions 1, 2, 3 and 6) based on the given data.
In all cases, this event does not have direct relation to the accident


3.5
Pitch up and airspeed decay
OR
Intended maneuver
Unintended maneuver
OR
Using FD
Not using FD
OR
FD pitch bar correct
FD pitch bar incorrect
OR
FCC Fault
MCP Fault


Legend:
Sufficient Data Collected at This Point
May Need More Data
Not Eval'd for Data Needs
1
6.0 Pitch Up and Airspeed Decay
NEWTOP
Intended Maneuver
Unintended Maneuver
G001
G002
Pilot Wanted to Gain Altitude Quicker
Pilot Following Erroneous FD (SCENARIO 17)
Relaxation of Control in Out of Trim Condition
Stab Trim Fault
G003
(CBS Work)
G007
M-Cab; Addtl Eval.
G005
M-CAB match with FDR
G008
FDR
Autopilot Fault
G006
Prior to AP Engagement per FDR

2.5.7 Autopilot engage sequence

Based on the CVR data, the Captain announced ‘Autopilot” at 92409, followed by “Not yet” at 92412. At 92413 FDR showed A/P engaged+ CWS-R

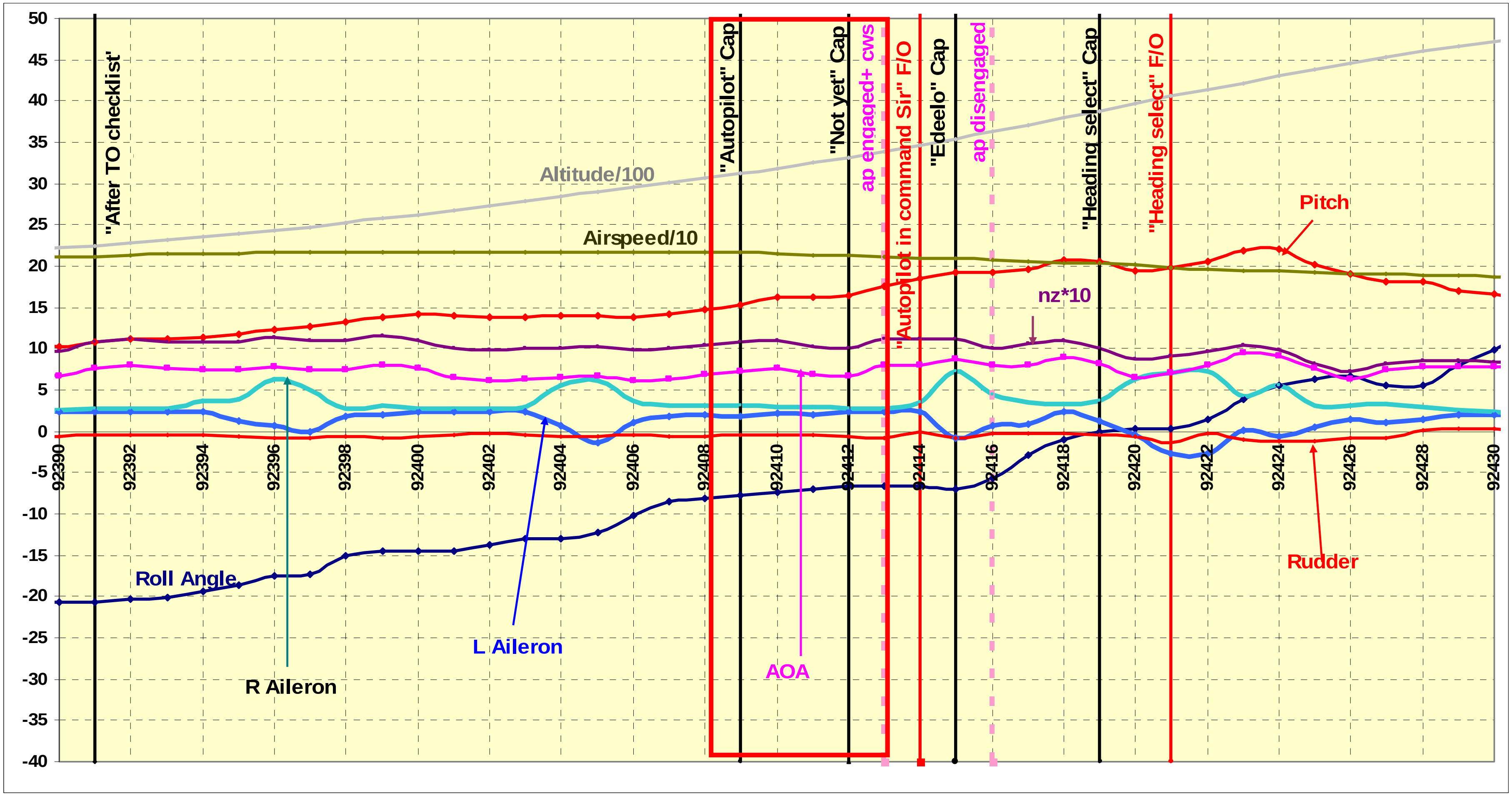


Figure 2.5.7.1 Autopilot engage sequence

2.5.7.1 Autopilot Engage Logic [1]

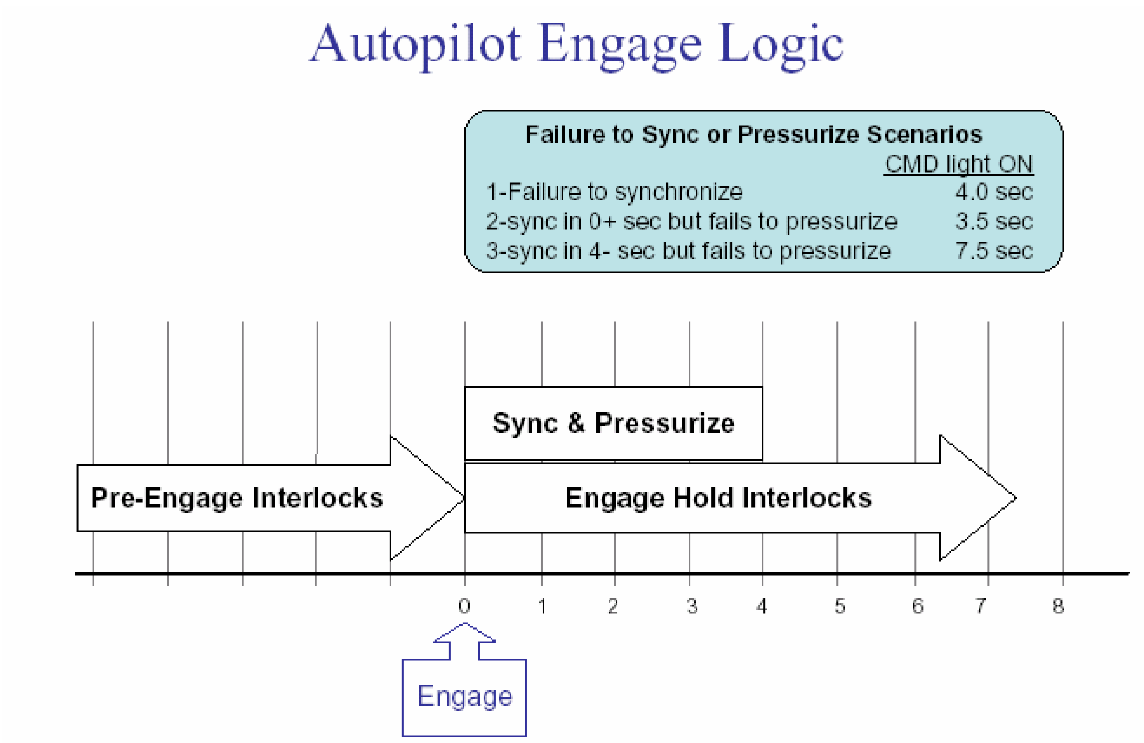


Figure 2.5.7.2a Autopilot Engage Logic

[1] Cairo March 04 Autopilot Flash 737 March Progress Meeting Flash 737 March Progress Meeting - Cairo

A/P Engage Function

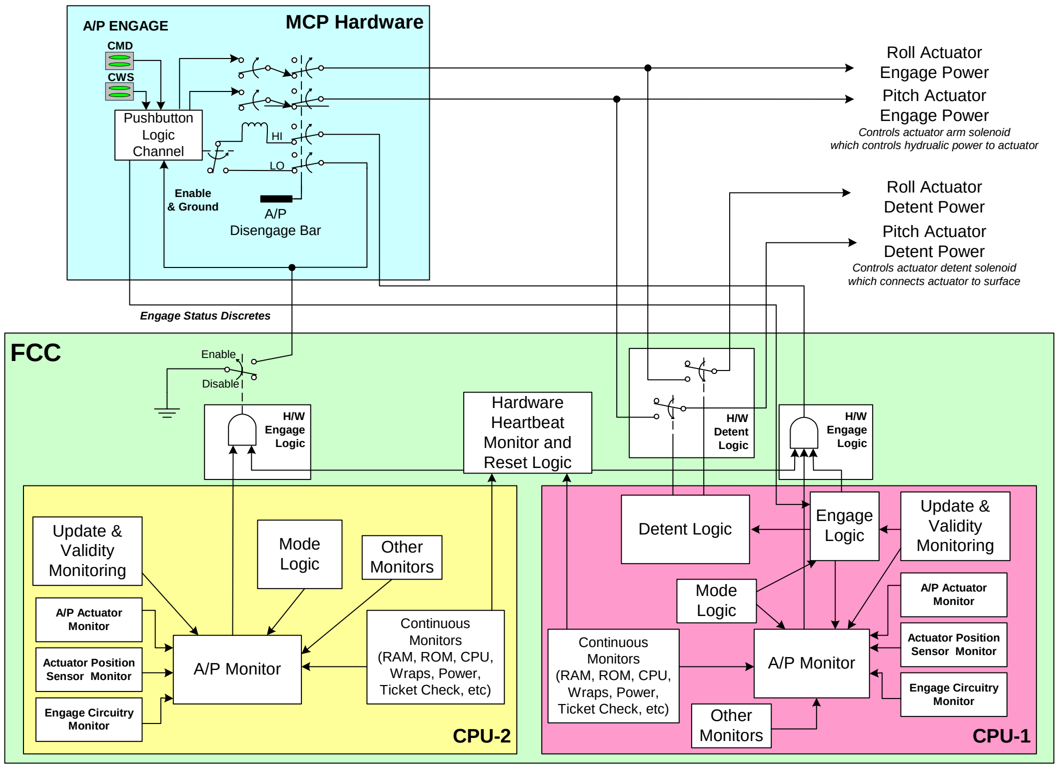


Figure 2.5.7.2b Autopilot Engage Logic

If the pre-engage logic is valid, pushing any of the autopilot switches (push/light type switches CMD and CWS) engages the autopilot and turns the light on. Once the light is on, a loss of the engage hold logic causes the light to go off and the autopilot disengages. If the pre-engage logic is not valid when the switch is pressed, the light does not turn on and the autopilot does not engage.

	UNLOCK	HOLD	DISENGAGE
1. A/P STAB TRIM CUTOUT SWITCH NORMAL	X	X	
2. MAIN ELECTRIC TRIM SWITCHES (NOT PRESSED)	X	X	
3. A/P STAB TRIM MOTOR SPEED VALID (10 SEC)	X	X	
4. AILERON FORCE LIMITER AUTHORITY LIMIT VALID (10 SEC)	X	X	
5. AILERON FORCE LIMITER CLUTCH - DISENGAGE [4]	X		
6. AILERON FORCE LIMITER CLUTCH - ENGAGE WITHIN 0.5 SEC [4]		X	
7. A/P DISENGAGE SWITCH NOT PRESSED	X	X	
8. A/P AILERON HYD PRESSURE SWITCH - NO PRESSURE	X		
9. A/P AILERON HYD PRESSURE SWITCH - PRESSURE WITHIN 3.5 SEC AFTER ACT DET SOL ENGAGED		X	
10. A/P ELEVATOR HYD PRESSURE SWITCH - NO PRESSURE	X		
11. A/P ELEVATOR HYD PRESSURE SWITCH - PRESSURE WITHIN 3.5 SEC AFTER ELEV ACT DET SOL ENGAGED		X	
12. FCC 115V AC (0.5 SEC)	X	X	
13. (DC) ENGAGE INTLK A	X	X	
14. NOT (FGN IN CMD AND APP PB AND LRRA <800 FT)	X		
15. FCC DC AND FCC POWER SUPPLY	X	X	
16. 1800 Hz POWER SUPPLY	X	X	
17. POWER UP TEST VALID	X		
18. CONTINUOUS MONITOR	X	X	
19. A/P ONLY CONTINUOUS MONITOR VALID	X	X	
20. LESS THAN 3 LB FORCE ON CONTROL WHEEL	X		
21. LESS THAN 5 LB FORCE ON CONTROL COLUMN	X		
22. SELECTED IRU ROLL ANGLE VALID (NORM - OFF SIDE)	X	X	
23. SELECTED IRU ROLL RATE VALID (NORM - OFF SIDE)	X	X	
24. SELECTED IRU PITCH ANGLE VALID (NORM - ON SIDE)	X	X	
25. SELECTED IRU PITCH RATE VALID (NORM - ON SIDE)	X	X	
26. A/P TO CMD AND R/A <400 FT WITH LOC AND GS ENGAGED			X
27. F/D IN TO OR GA, R/A ALT <400 FEET AND A/P TO CMD			X
28. ADC CAS NOT VALID (EXCEPT WITH MONITORS ACTIVE)			X
29. IRU TRANSFER (SEE TEXT)	[2]		[2]
30. A/P ENGAGE SWITCH SWAP (SEE TEXT)			X
31. ADC CORRECTED BARO ALT VALID	X		[1]
32. ADC UNCORRECTED BARO ALT VALID	X		[1]
33. LCL AC BUS TRANSFER (SINGLE SHOT)	[2]		[2]
34. A/P DISENGAGE SWITCH PRESSED			
35. DISENGAGE BAR ON MCP PULLED DOWN [3]			

[1] SEE PITCH MODE DISENGAGE TABLE

[2] DISENGAGES, CAN BE RE-ENGAGED IN ANY MODE EXCEPT APP MODE WITH FGN IN CMD

[3] MCP WITH PUSHBUTTON ENGAGE SWITCHES

[4] AIRPLANES WITH MECHANICAL AILERON FORCE LIMITER

Table 2.5.7.1 Autopilot Unlock, Hold and Disengage Logic

Autopilot Engage & Engage Hold Interlocks

	Pre-Engage	Engage Hold
Condition	Prevent Engage	Cause Disengage
Pitch CWS force greater than 5 lbs	X	
Roll CWS force greater than 2.25 lbs	X	
Elevator Detent Pressure Switch Indicates Pressurized	X	
Aileron Detent Pressure Switch Indicates Pressurized	X	
Auto Stab Trim Cutout Switch in Cutout	X	X
Both Flap Switches and Stab Trim Motor don't agree as Flaps Up or as Flaps Down	X	X
Main Electric Trim Switch Activated	X	X
Aileron Force Limiter position does not agree with Flaps UP or Flaps Down	X	X
CAS Invalid	X	X
Uncorrected Altitude Invalid	X	X
26 VAC 400 Hz Invalid	X	X
MCP to FCC Bus Invalid	X	X
Pitch Angle Invalid	X	X
Pitch Rate Invalid	X	X
Roll Angle Invalid	X	X
Roll Rate Invalid	X	X
Baro Altitude Invalid (Prevents CMD only)	X	X
Elevator Detent Pressure Switch Indicates Non-Pressurized		X
Aileron Detent Pressure Switch Indicates Non-Pressurized		X
(Magnetic Heading OR TAS Invalid) AND (Roll CWS) AND (Bank Angle <8 degrees)	X	X

Table 2.5.7.2 Autopilot Engage, Engage Hold Logic

2.5.7.2 Autopilot engagement attempt analysis based on the FDR and CVR data:

2.5.7.2.1 Based on the FDR recorded data, the autopilot was engaged for few seconds and then disengaged, meaning that the pre-engage logic was valid, i.e. the following logic was valid:

- Pitch CWS force was not greater than 5 lbs, and
- Roll CWS force was not greater than 2.25 lbs, and
- Elevator Detent Pressure Switch indicates no pressure, and
- Aileron Detent Pressure Switch indicates no pressurized, and
- Auto Stab Trim Cutout Switch was not in Cutout, and
- Both Flap Switches and Stab Trim Motor agree as Flaps Up or as Flaps Down , and
- Main Electric Trim Switch not Activated, and
- Aileron Force Limiter position agrees with Flaps UP or Flaps Down, and
- CAS valid, and
- Uncorrected Altitude valid, and
- 26 VAC 400 Hz valid, and
- MCP to FCC Bus valid, and
- Pitch Angle valid, and
- Pitch Rate valid, and
- Roll Angle valid, and
- Roll Rate valid, and
- Baro Altitude

2.5.7.2.2 The conditions leading to the event of engaging the autopilot are presented in the following:

1. Captain requests autopilot, Captain cancels request, F/O pushes CMD button anyway

   This probability is consistent with Flash Airline company practice. Impression from CVR is that the first officer is manipulating the MCP Controls prior to autopilot engagement.CMD button is located on right side of MCP, closer to F/O.

   However, Boeing procedure is for “pilot flying” to push the CMD button.

2. Captain requests autopilot, Captain prompts F/O due slow response, F/O pushes CMD button

   This probability is consistent with Flash Airline company practice Impression from CVR is that the first officer is manipulating the MCP, Controls prior to autopilot engagement, CMD button is located on right side of MCP, closer to F/O.

However, Boeing procedure is for “pilot flying” to push the CMD button.

3. Captain pushes CMD button, gets no response., Captain questions no response and makes second push., F/O reports autopilot engaged.

   Boeing procedure is for “pilot flying” to push the CMD button

Conclusion:

The investigation could not determine a higher possibility to any of the above findings based on the given data. However, with reference to the CVR/ FDR correlation, this event could have initiated crew distraction.

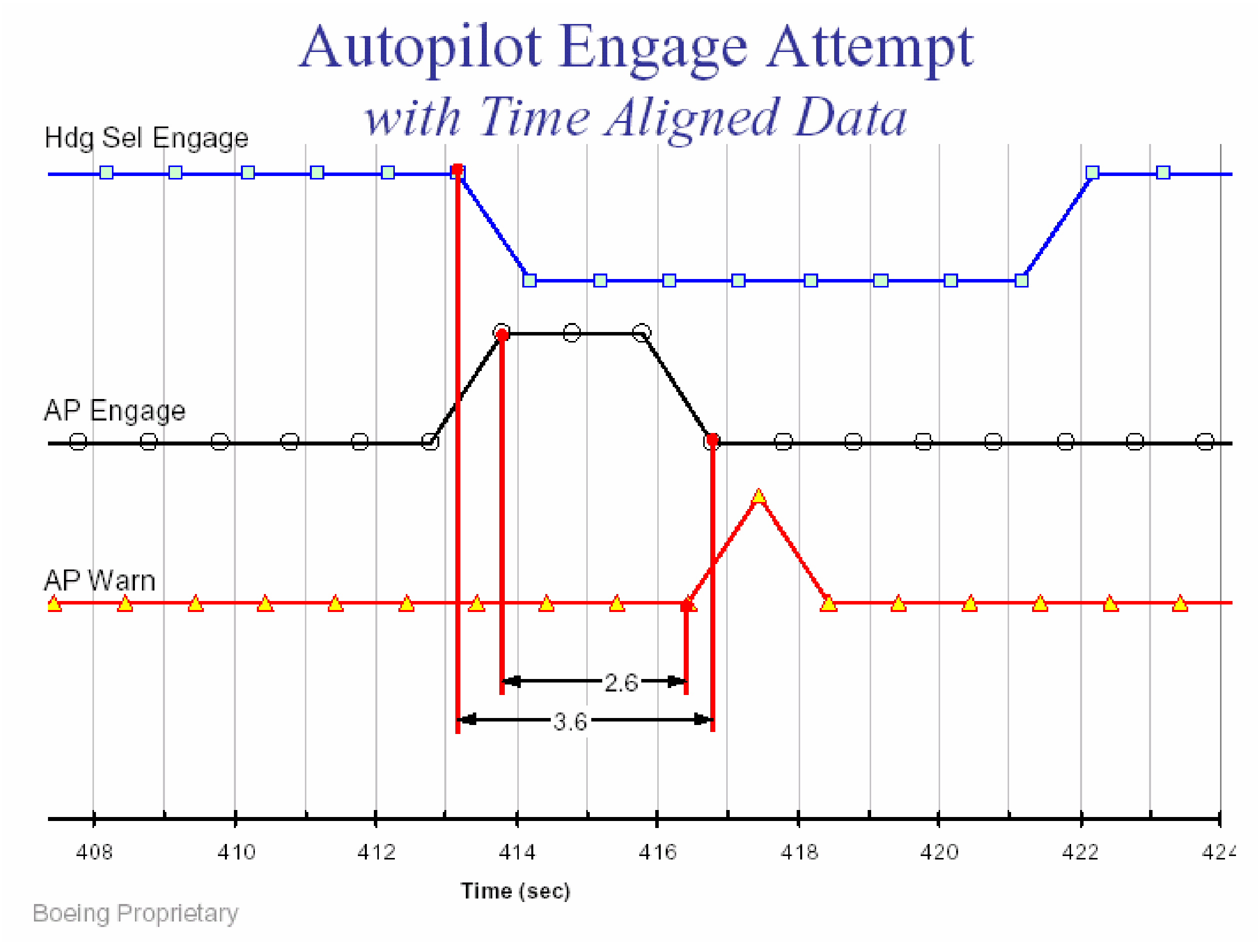
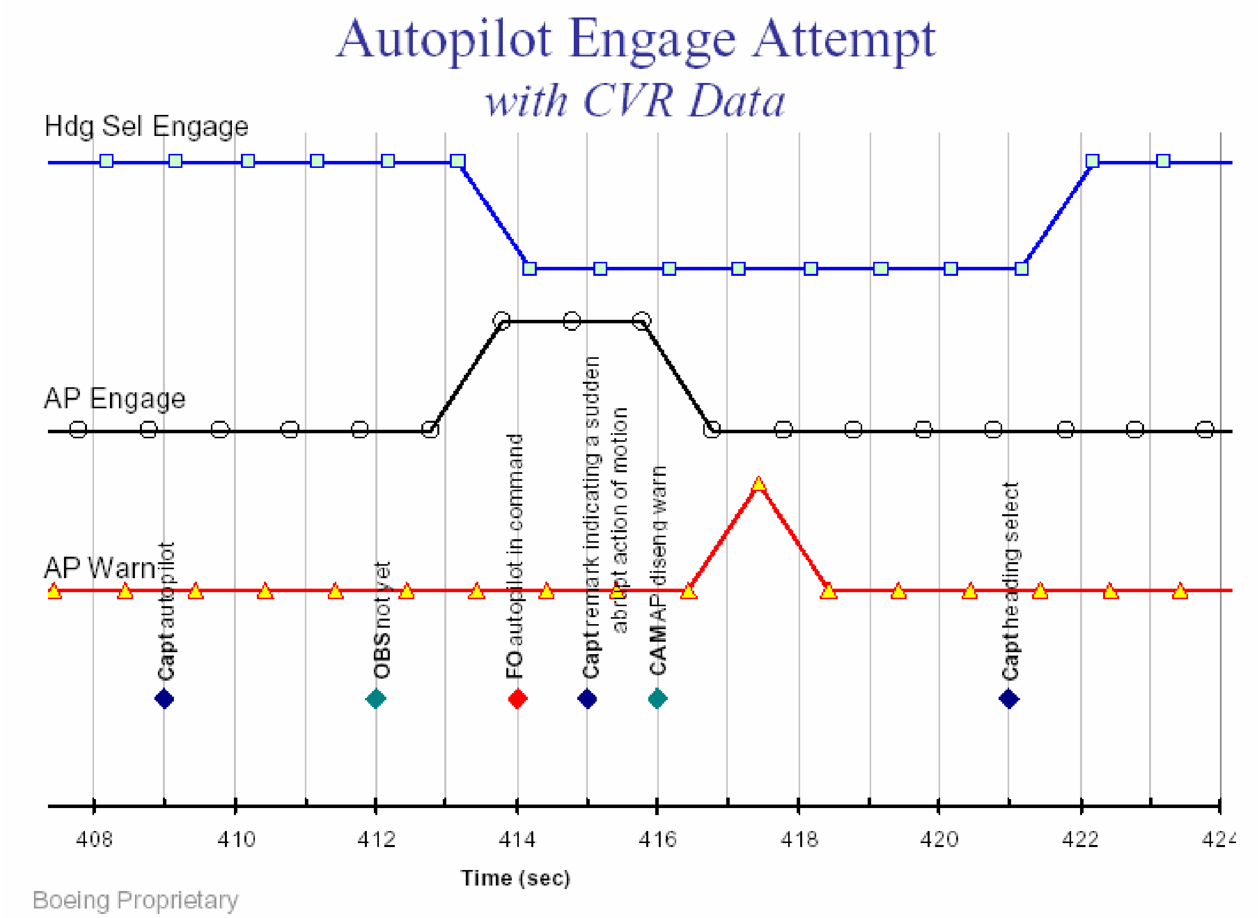


Figure 2.5.7.3 Autopilot Engage Attempt with Time Aligned Data



The CVR statement "Not yet" at 412 is attributed to Captain instead of the Observer

Figure 2.5.7.4 Autopilot Engage Attempt with Time CVR Data

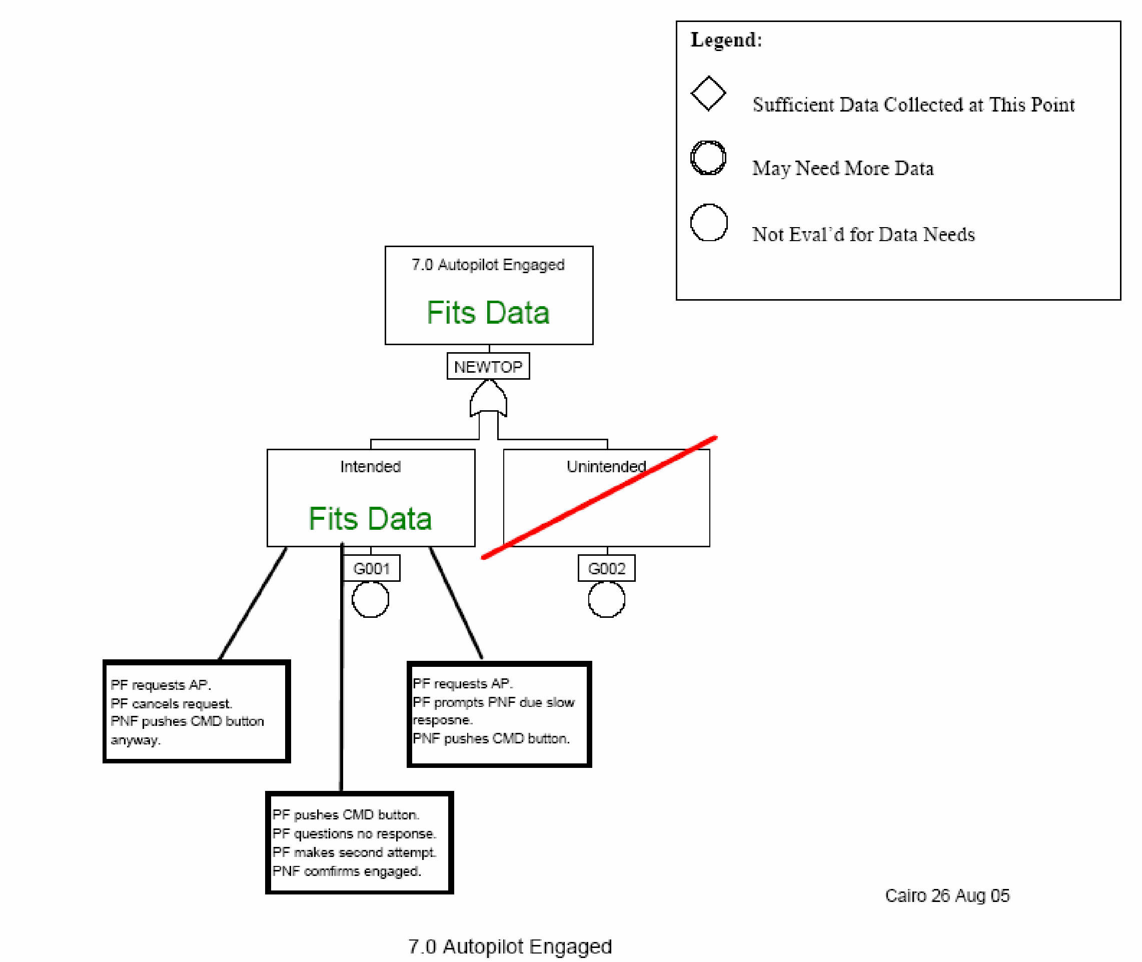


Figure 2.5.7.5 Autopilot Engage fault Tree Analysis

2.5.8 Mode change from HDG SEL to CWS-R

At 92413 FDR showed A/P engaged+ CWS-R

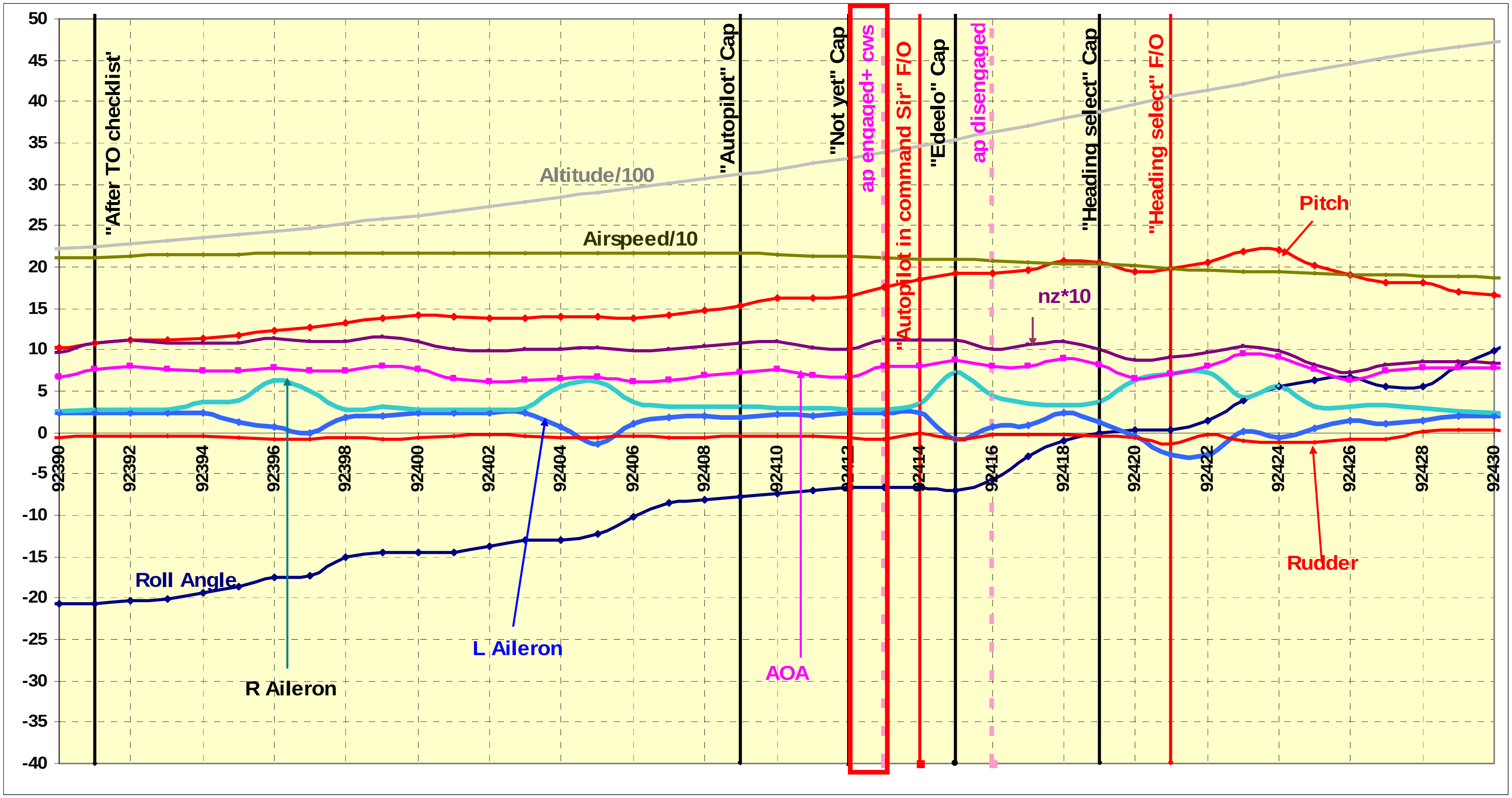


Figure 2.5.8 Mode change from HDG SEL to CWS-R

2.5.8.1 Possible conditions leading to "Heading Select Mode Fails Off"

1. Loss of TAS (True Air Speed)
   Unlikely to be the cause of the event as it would have also caused loss of level change. Level change was not lost

2. Loss of "Magnetic Heading"
   Unlikely to be the cause of the event because the Magnetic Heading was available immediately before and is valid on FDR

3. MCP (Mode Control Panel) Fault
   This condition could be ruled out

3. FCC Fault (Unpredictable)
   This condition could be ruled out

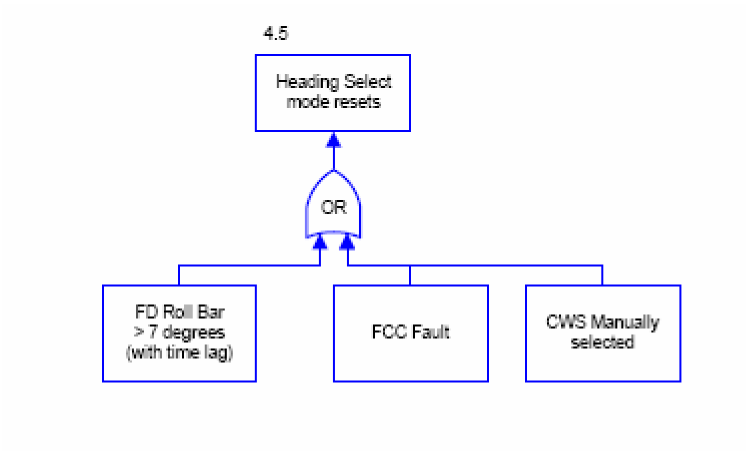
5. CWS Manually Selected (no failures condition)
   Unlikely to occur simultaneously with AP engagement

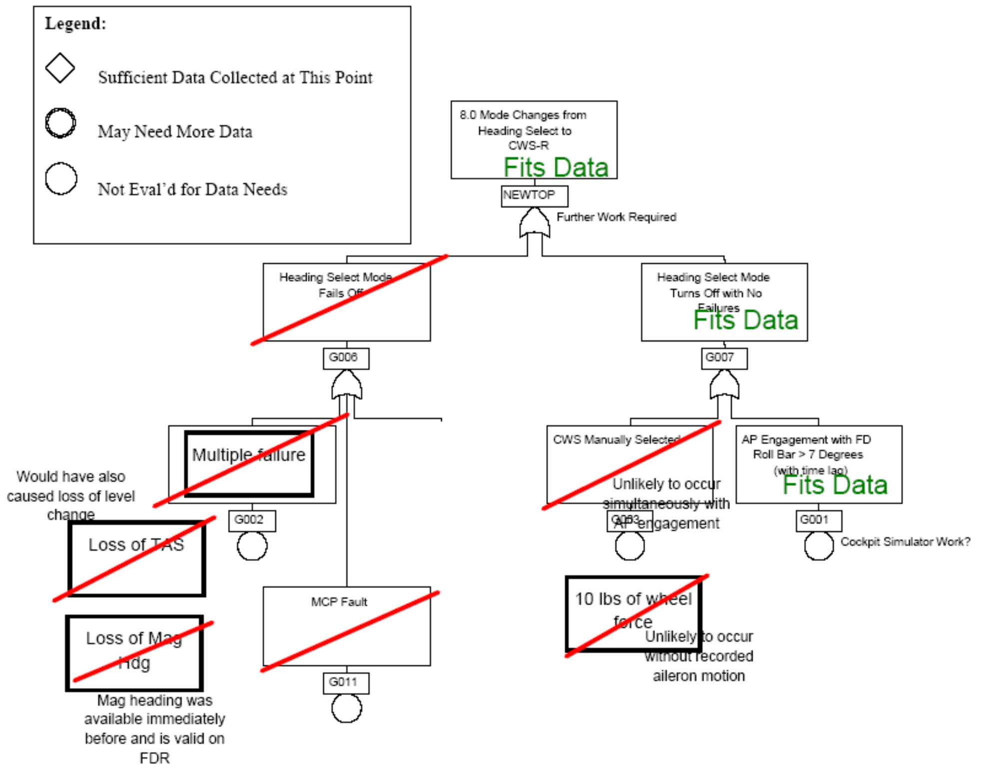
6. 10 lbs (or higher) of wheel force ((no failures condition)
   Unlikely to occur without recorded aileron motion

7. AP Engagement with FD Roll Bar > 7 Degrees (with time lag) (no failures condition)
   If the FD director command is greater than 7 degrees at the time autopilot engagement is attempted, the roll mode will change from HDG SEL to CWS. According to FDR data this seems to be consistent with the probable FD command which existed when A/P engagement was initiated.
   This condition could not be ruled out.

Conclusion:

After ruling out the conditions which are unlikely to occur as mentioned above, the possible condition that could have led to this event is that the autopilot was Engaged with FD Roll Bar > 7 Degrees (with time lag)





Updated: 10/1/04 (Seattle)

2.5.9 Aileron move in direction of right roll

Based on the FDR, the ailerons started moving in the direction requesting for airplane right roll almost after 92392

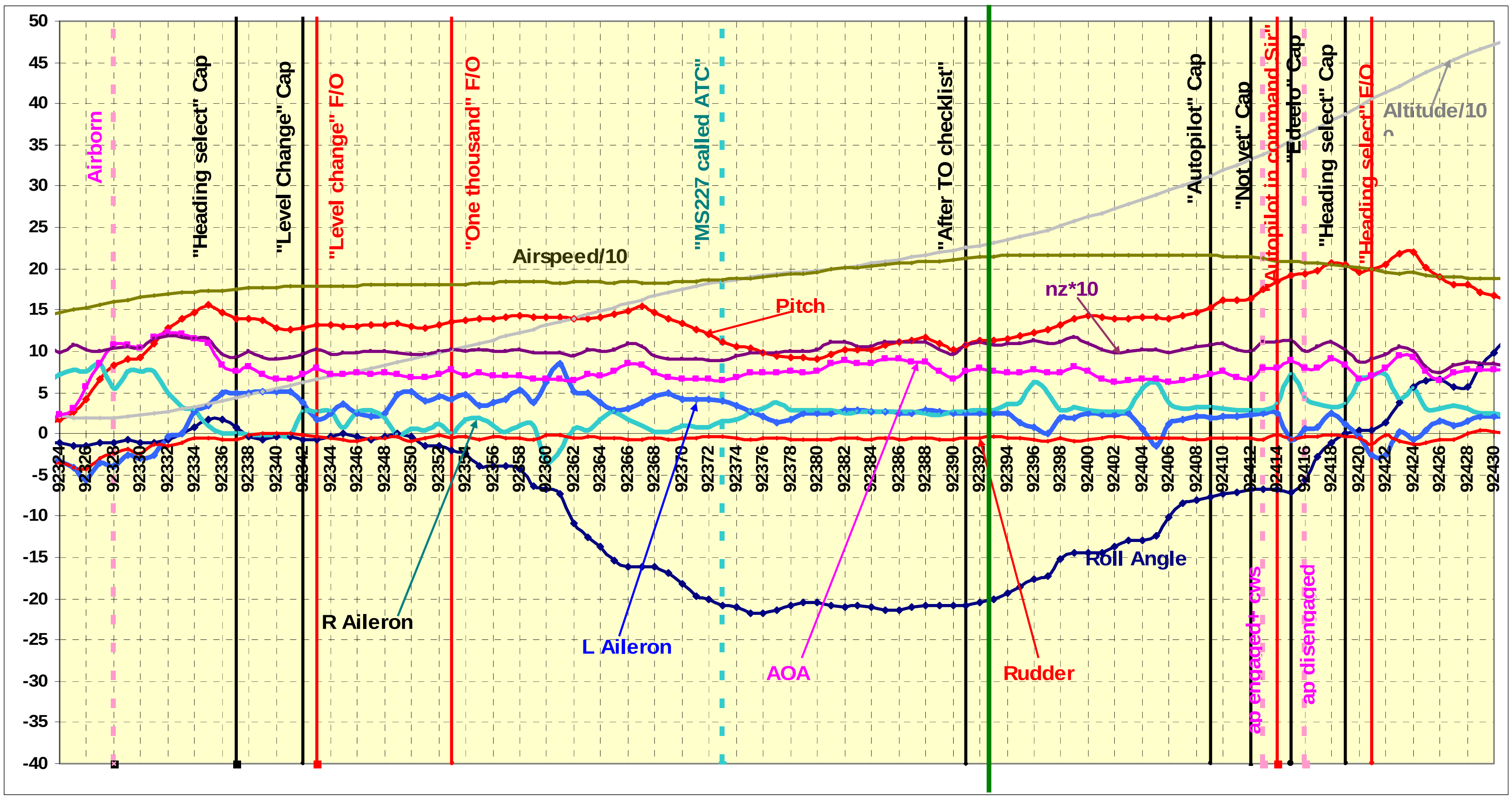


Figure 2.5.9.1a Aileron Move in direction of right roll

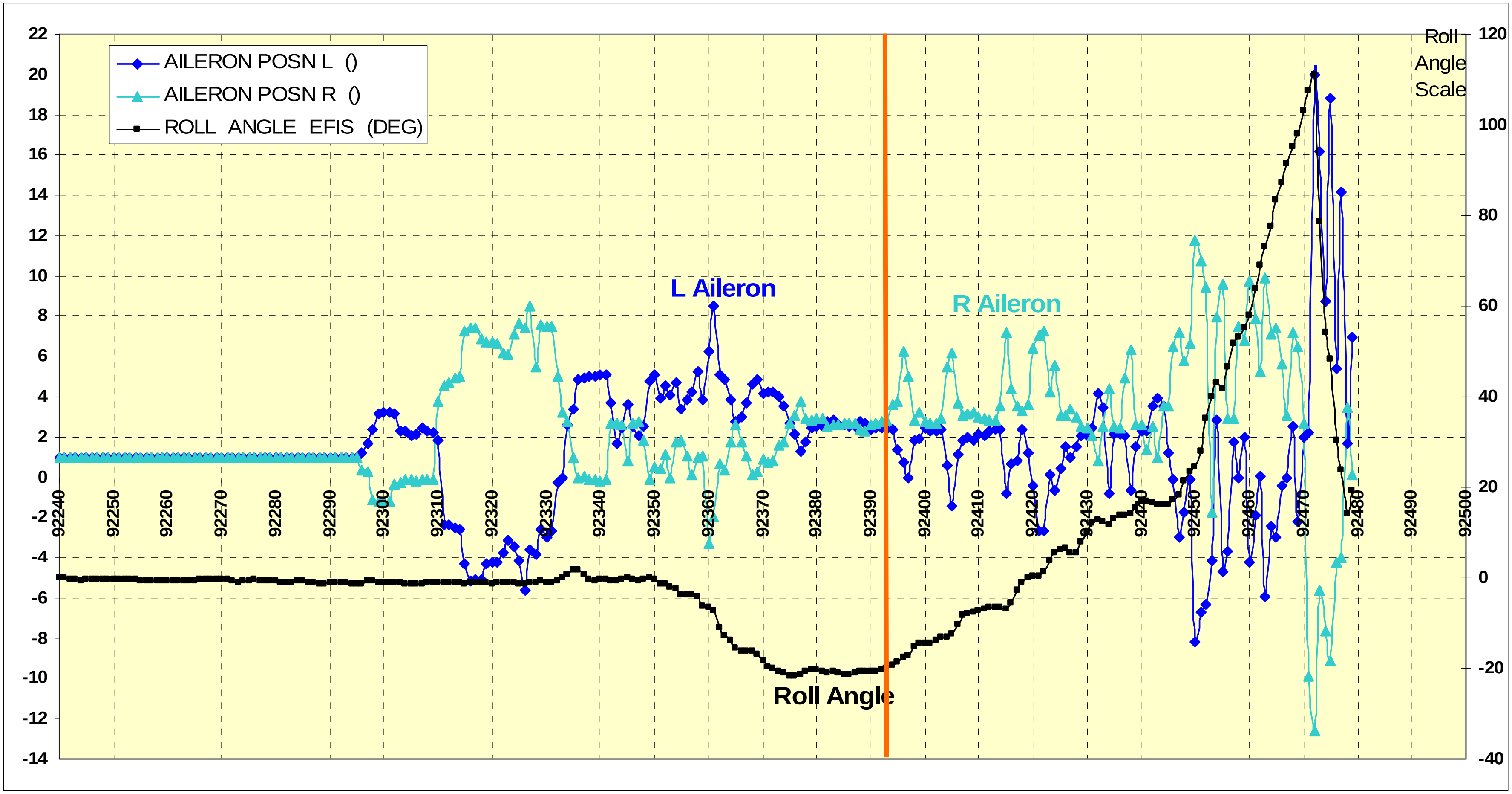


Figure 2.5.9.1b Aileron Move in direction of right roll

Based on the FDR data, and starting from about the time frame 92393 the right aileron showed upward movement (TEU), the left aileron showed downward movement. This movement dirction continued up to the 92471 timeframe after which airplane recovery attempt was made.

Probable conditions leading to the event:

A. NA:

B- Flaps assymetry:

The FDR did not show evidences of flap asymmetry. Based on these information, there is no evidence of flap asymmetry existing at the time of the event and consequently this condition could be ruled out

C- Slats assymetry:

1.1 Uncommanded Deployment

Based on the performance evaluation, Slat failure simulations that were conducted on computer workstations, this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

1.2 Remains Deployed (SLAT FULL DEPLOYED)

Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

D- Thrust assymetry

With reference to section “2.3.6. Power plants”, it is shown that all the engines parameters were recorded in the FDR. However, some parameters data were not reliable (e.g. L engine N1). The other engines parameters are reliable including the N2 for both engines.. Based on these information, there is no evidence of thrust assymetry existing at the time of the event and consequently this condition could be ruled out

E- External Disturbance

This condition could be ruled out based on FDR data, M- Cab Simulator Match to FDR and meteorogical data

F- Lateral control system

1- Pilot input

This condition could not be ruled out

2- Autopilot Initiated

- CWS Bank Hold

  In this condition, the autopilot would command faired ailerons. Thus, this condition could be ruled out

- CWS Heading Hold

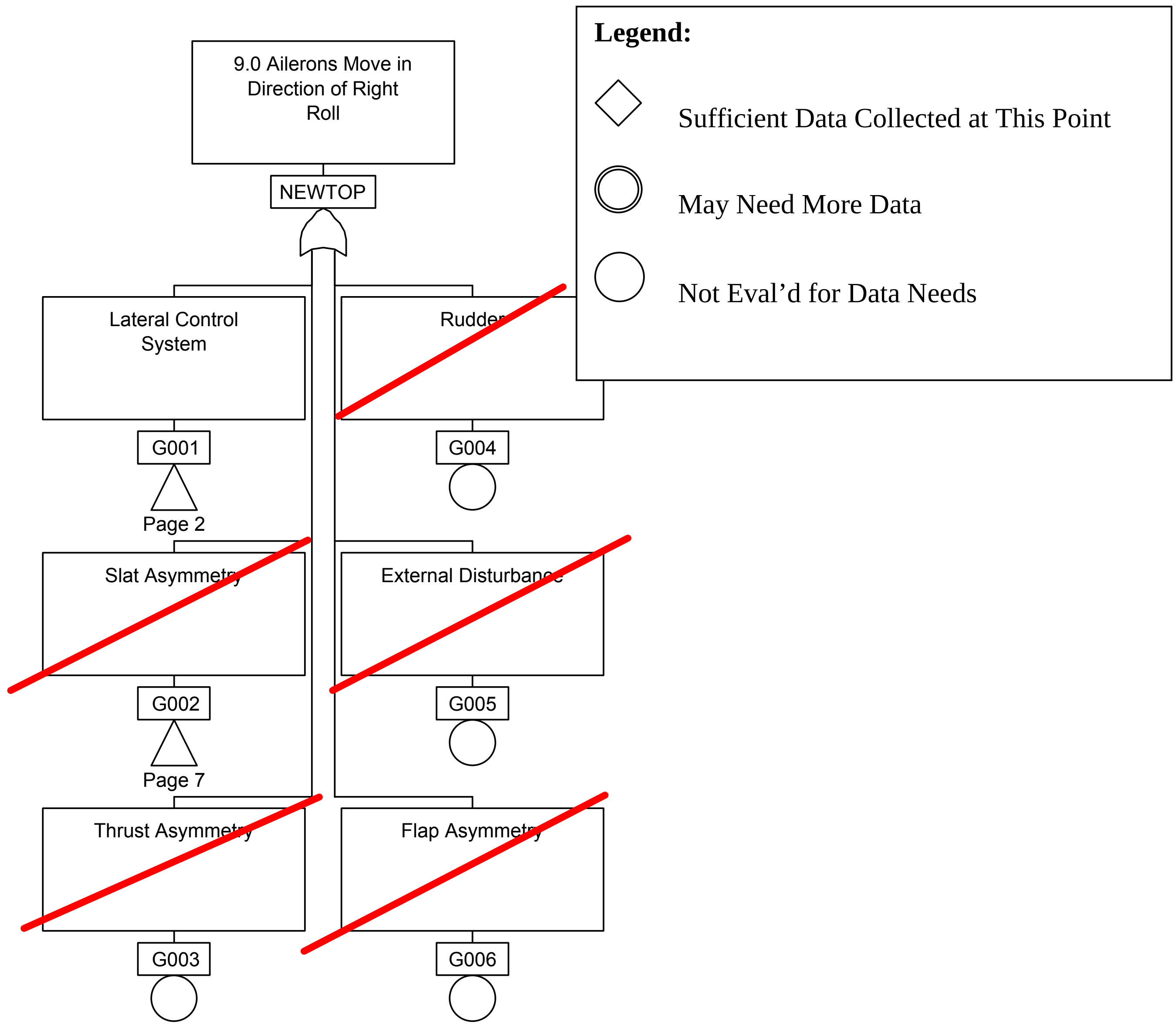
  Normally this mode would not engage past 6 deg of airplane bank. The roll angle as shown by the FDR was higher than 6 degrees. Thus, this condition could be ruled out

3- Lateral system fault:

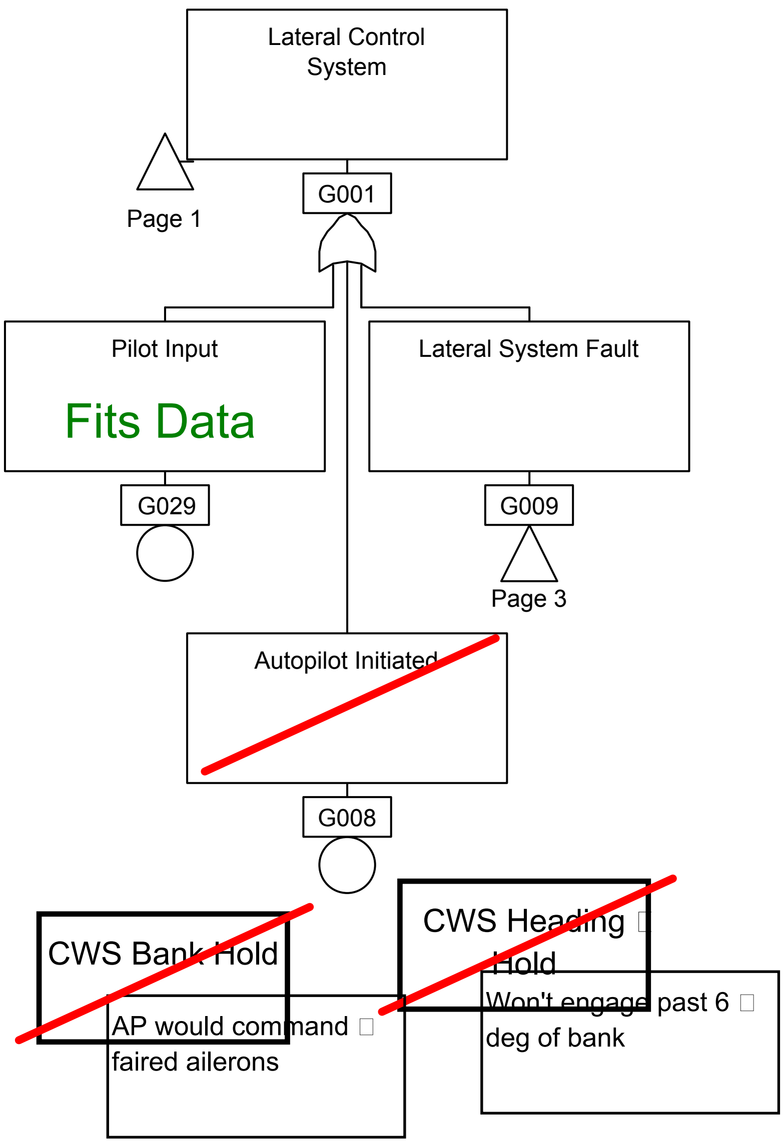
See Appendix 2-1 lateral control analysis, and section 2.5.13 Right roll continues to overbank with ailerons activities, item 1.1 Lateral control system

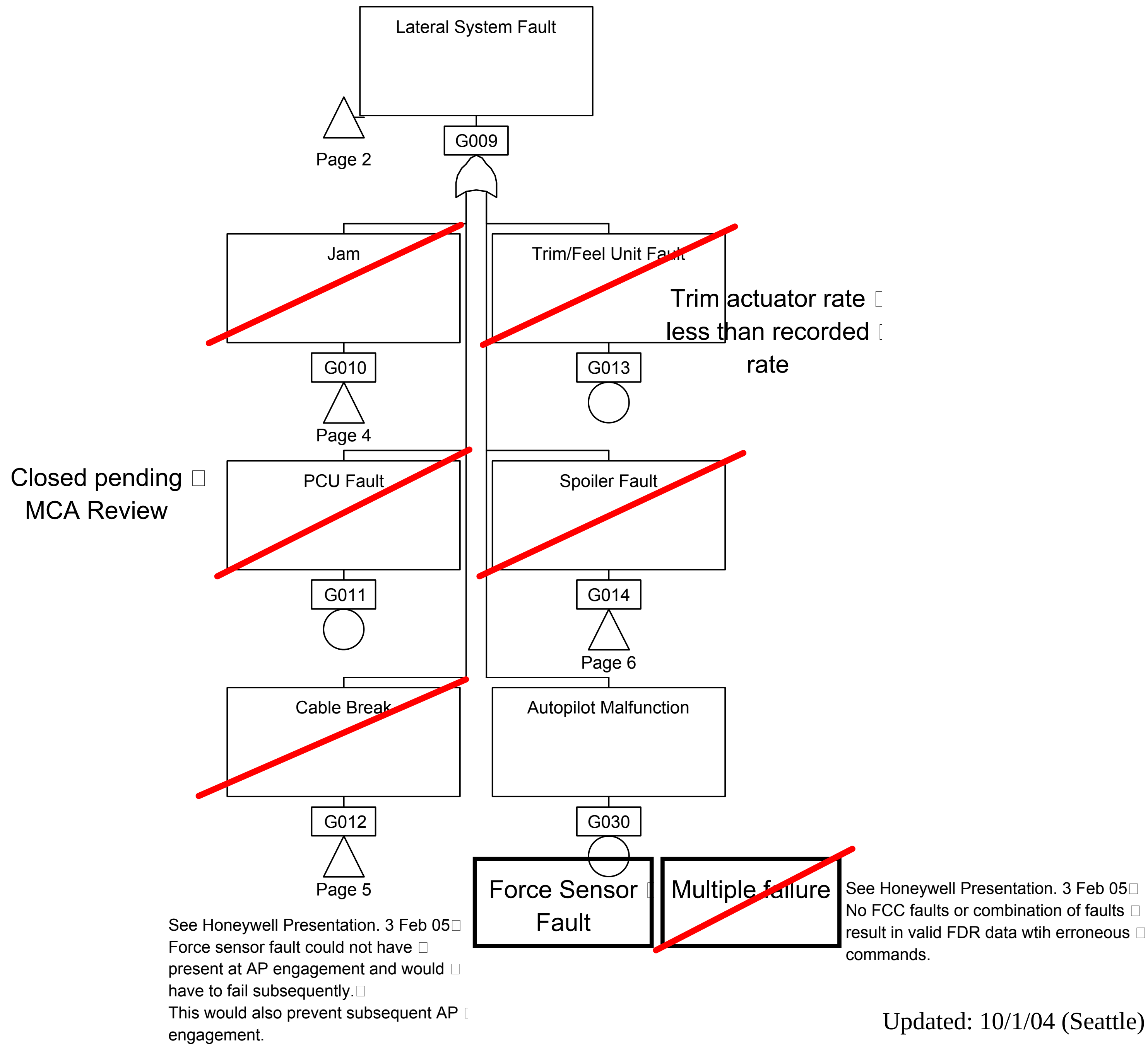
Conclusion:

The investigation could not determine a higher possibility to any of the above findings (lateral system fault, pilot input) based on the given data.



Updated: 10/1/04 (Seattle)


Lateral Control System
Page 1
G001
Pilot Input
Fits Data
Lateral System Fault
G029
G009
Page 3
Autopilot Initiated
G008
CWS Bank Hold
AP would command faired ailerons
CWS Heading Hold
Won't engage past 6 deg of bank



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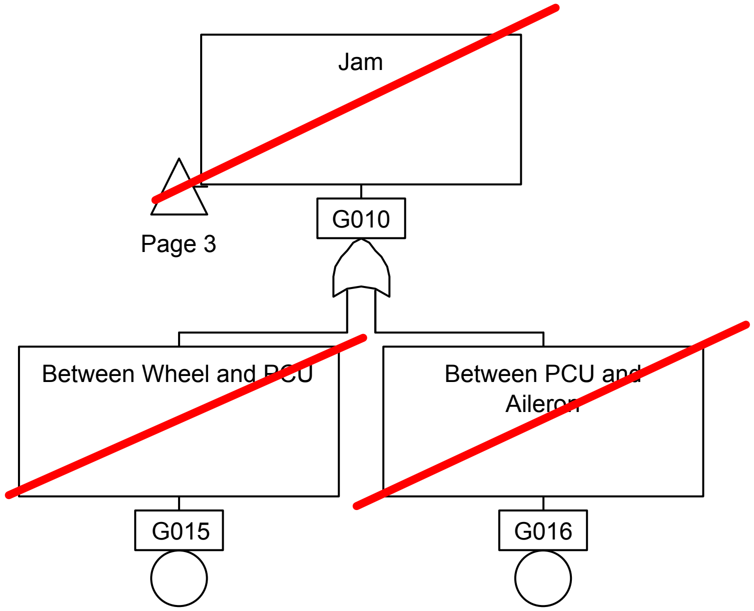
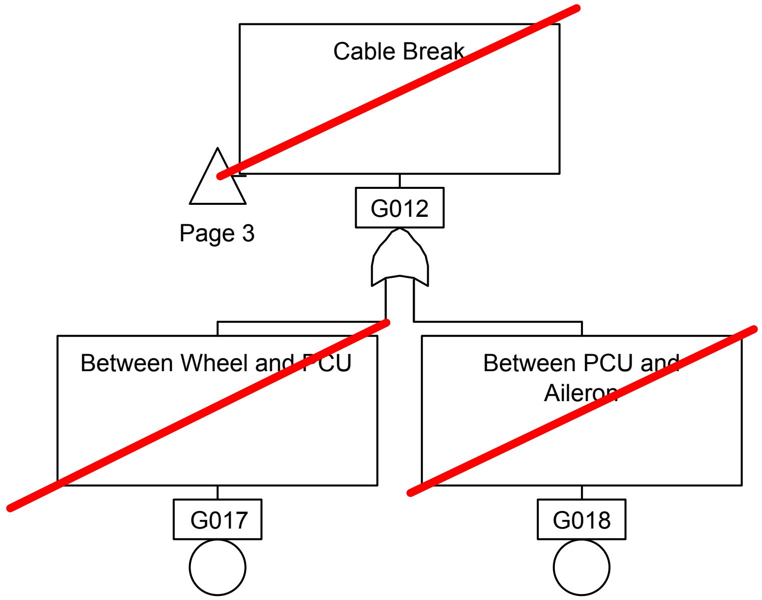
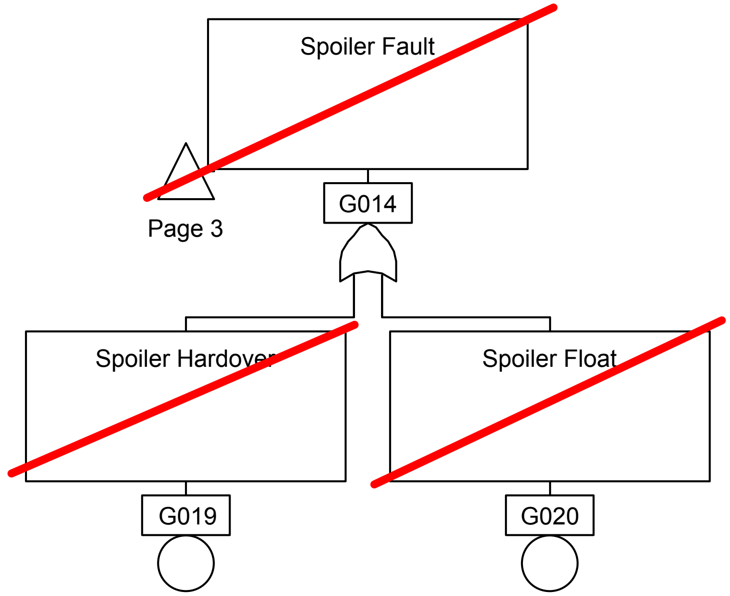
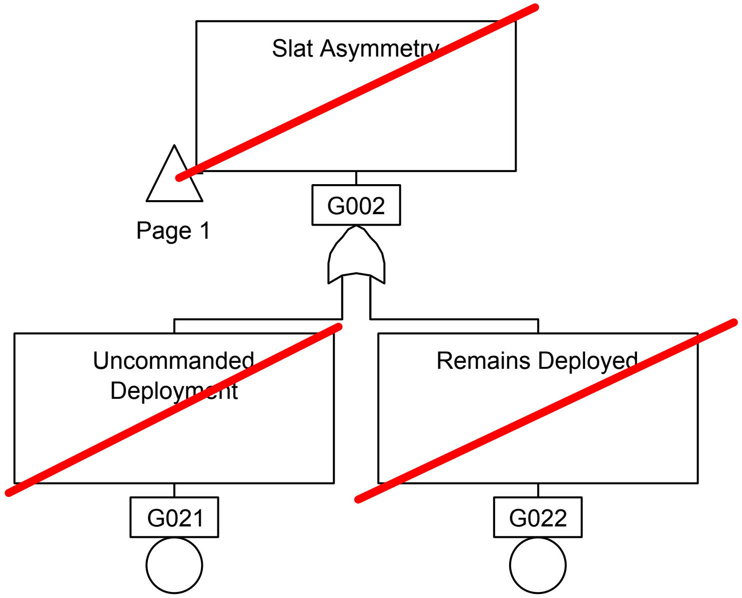

Jam
Page 3
G010
Between Wheel and PCU
Between PCU and Aileron
G015
G016


Cable Break
Page 3
G012
Between Wheel and PCU
Between PCU and Aileron
G017
G018



Spoiler Fault
Page 3
G014
Spoiler Hardover
Spoiler Float
G019
G020


Slat Asymmetry
Page 1
G002
Uncommanded Deployment
Remains Deployed
G021
G022

2.5.10 Autopilot Disengagement indications on the FDR and CVR

Based on FDR and CVR information:

- At time 02:43:55 (92409), the Captain called "Autopilot".

- At time 02:43:58 (92412), the Captain stated "Not yet".

- At time 02:43:59 (92413), the FDR recorded the autopilot was engaged, and the roll mode transition to CWS-R[1].

- At time 02:44:00 (92414), the F/O stated "Autopilot in command sir".

- At time 02:44:01 (92415), the captain stated "EDEELO", (an Arabic exclamation expressing a sharp response of some kind). At the same time, the FDR records momentary aileron surfaces movements. The right aileron deflected to 7.2 degree TEU for one second

- At time 02:44:02 (92416), the CVR recorded the autopilot disconnect warning and the FDR recorded the autopilot disengaged. The aural warning lasted for 2.136 seconds. During this time, an increase in pitch and decay in airspeed were observed

[1] This transition would have resulted in loss of Heading Select Mode

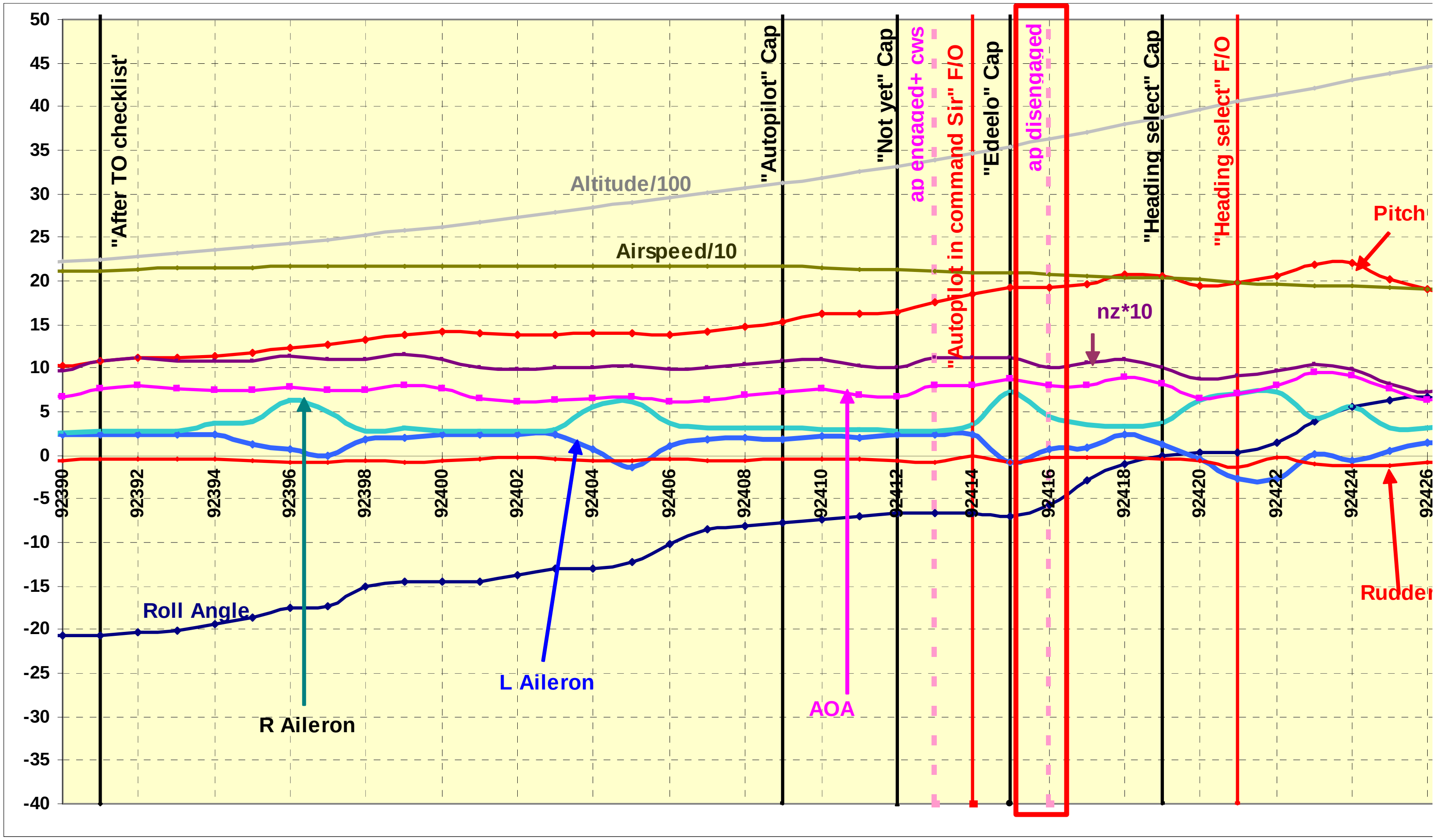


Figure 2.5.10.1 Autopilot Disengagement indications on the FDR and CVR

2.5.10.1 B737-300 Autopilot Engage/ Hold/ Disengage Logic:

BOEING
737-300/400/500
MAINTENANCE MANUAL

	UNLOCK	HOLD	DISENGAGE
1. A/P STAB TRIM CUTOUT SWITCH NORMAL	X	X	
2. MAIN ELECTRIC TRIM SWITCHES (NOT PRESSED)	X	X	
3. A/P STAB TRIM MOTOR SPEED VALID (10 SEC)	X	X	
4. AILERON FORCE LIMITER AUTHORITY LIMIT VALID (10 SEC)	X	X	
5. AILERON FORCE LIMITER CLUTCH - DISENGAGE ▷4	X		
6. AILERON FORCE LIMITER CLUTCH - ENGAGE WITHIN 0.5 SEC ▷4		X	
7. A/P DISENGAGE SWITCH NOT PRESSED	X	X	
8. A/P AILERON HYD PRESSURE SWITCH - NO PRESSURE	X		
9. A/P AILERON HYD PRESSURE SWITCH - PRESSURE WITHIN 3.5 SEC AFTER ACT DET SOL ENGAGED		X	
10. A/P ELEVATOR HYD PRESSURE SWITCH - NO PRESSURE	X		
11. A/P ELEVATOR HYD PRESSURE SWITCH - PRESSURE WITHIN 3.5 SEC AFTER ELEV ACT DET SOL ENGAGED		X	
12. FCC 115V AC (0.5 SEC)	X	X	
13. (DC) ENGAGE INTLK A	X	X	
14. NOT (FGN IN CMD AND APP PB AND LRRA <800 FT)	X		
15. FCC DC AND FCC POWER SUPPLY	X	X	
16. 1800 Hz POWER SUPPLY	X	X	
17. POWER UP TEST VALID	X		
18. CONTINUOUS MONITOR	X	X	
19. A/P ONLY CONTINUOUS MONITOR VALID	X	X	
20. LESS THAN 3 LB FORCE ON CONTROL WHEEL	X		
21. LESS THAN 5 LB FORCE ON CONTROL COLUMN	X		
22. SELECTED IRU ROLL ANGLE VALID (NORM - OFF SIDE)	X	X	
23. SELECTED IRU ROLL RATE VALID (NORM - OFF SIDE)	X	X	
24. SELECTED IRU PITCH ANGLE VALID (NORM - ON SIDE)	X	X	
25. SELECTED IRU PITCH RATE VALID (NORM - ON SIDE)	X	X	
26. A/P TO CMD AND R/A <400 FT WITH LOC AND GS ENGAGED			X
27. F/D IN TO OR GA, R/A ALT <400 FEET AND A/P TO CMD			X
28. ADC CAS NOT VALID (EXCEPT WITH MONITORS ACTIVE)			X
29. IRU TRANSFER (SEE TEXT)	▷2		▷2
30. A/P ENGAGE SWITCH SWAP (SEE TEXT)			X
31. ADC CORRECTED BARO ALT VALID	X		▷1
32. ADC UNCORRECTED BARO ALT VALID	X		▷1
33. LCL AC BUS TRANSFER (SINGLE SHOT)	▷2		▷2
34. A/P DISENGAGE SWITCH PRESSED			
35. DISENGAGE BAR ON MCP PULLED DOWN ▷3			

▷1 SEE PITCH MODE DISENGAGE TABLE

▷2 DISENGAGES, CAN BE RE-ENGAGED IN ANY MODE EXCEPT APP MODE WITH FGN IN CMD

▷3 MCP WITH PUSHBUTTON ENGAGE SWITCHES

▷4 AIRPLANES WITH MECHANICAL AILERON FORCE LIMITER

22-11-01

Page 54
Nov 12/01

Table 2.5.10.1 Autopilot Unlock, Hold, Disengage Logic

Autopilot Engage & Engage Hold Interlocks

	Pre-Engage	Engage Hold
Condition	Prevent Engage	Cause Disengage
Pitch CWS force greater than 5 lbs	X	
Roll CWS force greater than 2.25 lbs	X	
Elevator Detent Pressure Switch Indicates Pressurized	X	
Aileron Detent Pressure Switch Indicates Pressurized	X	
Auto Stab Trim Cutout Switch in Cutout	X	X
Both Flap Switches and Stab Trim Motor don't agree as Flaps Up or as Flaps Down	X	X
Main Electric Trim Switch Activated	X	X
Aileron Force Limiter position does not agree with Flaps UP or Flaps Down	X	X
CAS Invalid	X	X
Uncorrected Altitude Invalid	X	X
26 VAC 400 Hz Invalid	X	X
MCP to FCC Bus Invalid	X	X
Pitch Angle Invalid	X	X
Pitch Rate Invalid	X	X
Roll Angle Invalid	X	X
Roll Rate Invalid	X	X
Baro Altitude Invalid (Prevents CMD only)	X	X
Elevator Detent Pressure Switch Indicates Non-Pressurized		X
Aileron Detent Pressure Switch Indicates Non-Pressurized		X
(Magnetic Heading OR TAS Invalid) AND (Roll CWS) AND (Bank Angle <8 degrees)	X	X

Table 2.5.10.2 Autopilot Engage, Engage Hold interlock

Autopilot "Engaged" means:

Autopilot system began an attempt to synchronize so that it could subsequently control the airplane. It does not necessarily mean that the detent pistons were pressurized and that the autopilot was controlling the airplane.

This definition is consistent with indications of autopilot engagement available to crew and FDR.

Autopilot disengagement:

Any of the following three conditions cause autopilot disengagement:

A. The engage synchronization (actuator to surface) & pressurization failed to complete
(Failure to synchronize 4.0 sec/ sync in 0+ sec but fails to pressurize 3.5 sec/ sync in 4- sec but fails to pressurize 7.5 sec)

.

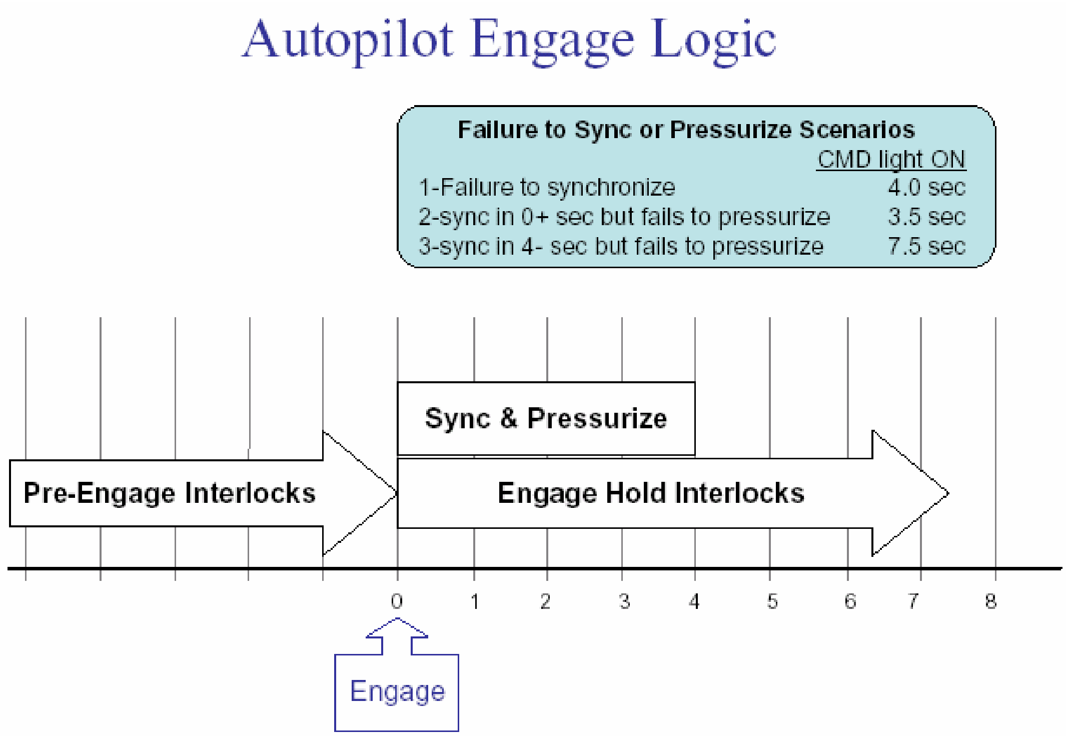


Figure 2.5.10.2 Autopilot Engage Logic

A.1 The engage synchronization:

The first step of autopilot engagement is synchronization. The arm solenoid opens and the FCC issues transfer valve commands to move the autopilot pistons to match the current location of the output crank. However, since the detent solenoid is closed, the detent pistons are free to move and the autopilot piston motion does not affect the output crank to the lateral system.
The FDR receives the ailerons position data; however, the autopilot actuator piston position is not recorded.

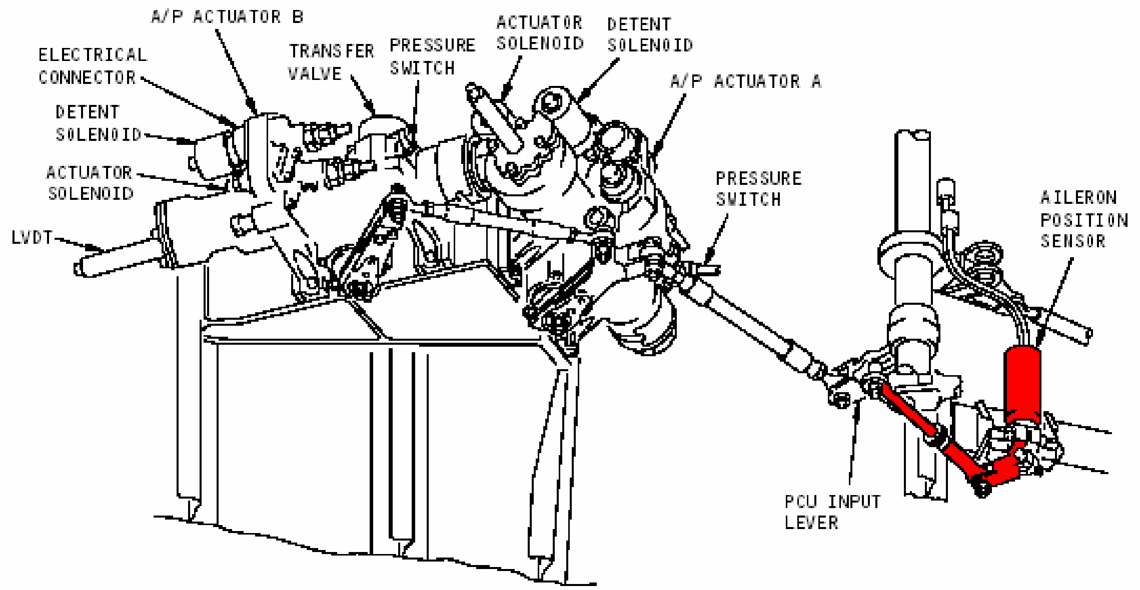


Fig 2.5.10.3 Roll channel autopilot actuator and position sensor[2]

[2] Refer to AMM *22-11-01, Page 20 for sensors description and operation*

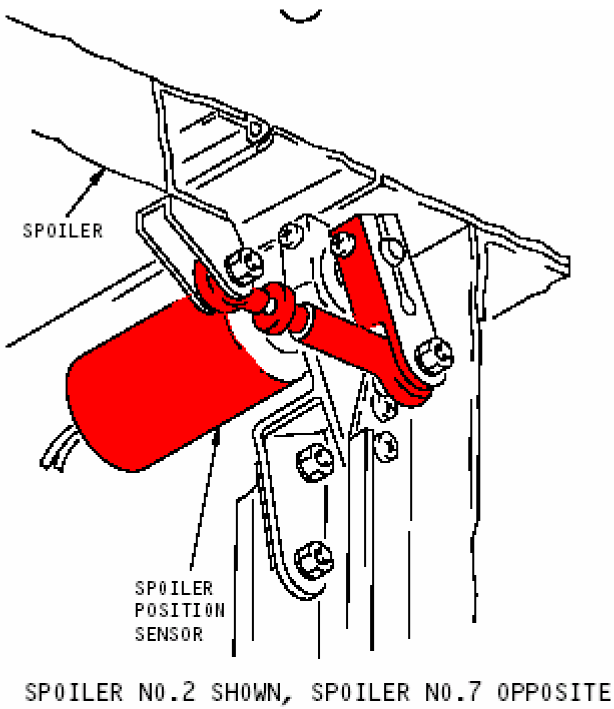


Fig 2.5.10.3 Spoiler sensor

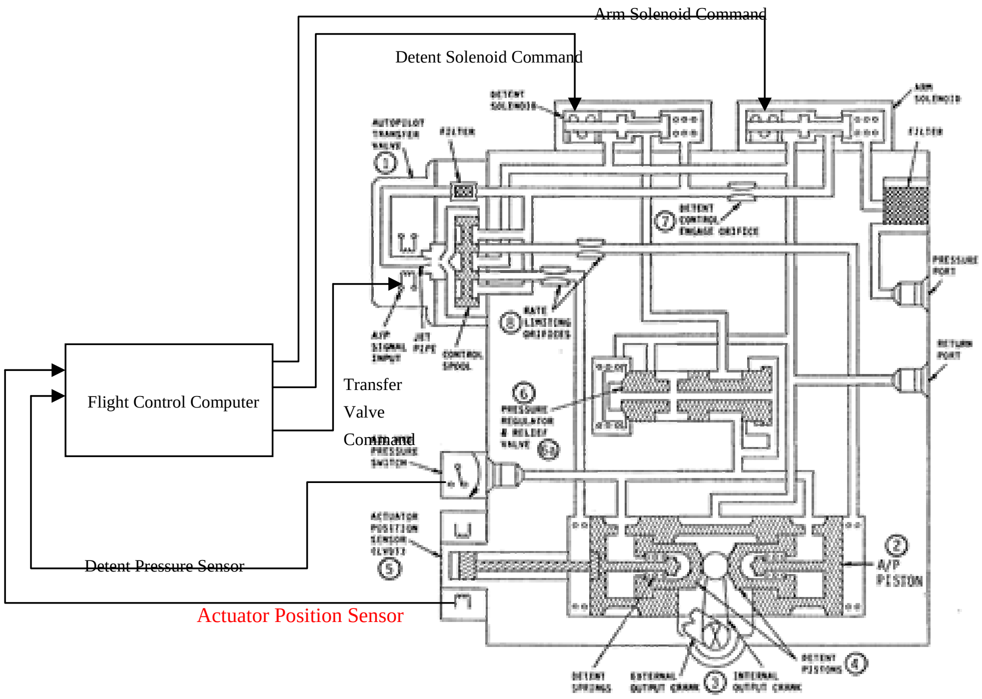


Fig 2.5.10.3 Autopilot Actuator

A.2 Pressurization:

Hydraulic pressure must be sensed at the autopilot aileron hydraulic switch (pressure switch on the autopilot actuator) within 3.5 seconds after actuator detent solenoid engaged; however, the FDR does not record data regarding the hydraulic pressure at the autopilot aileron hydraulic switch.

B. The engage hold interlocks not satisfied

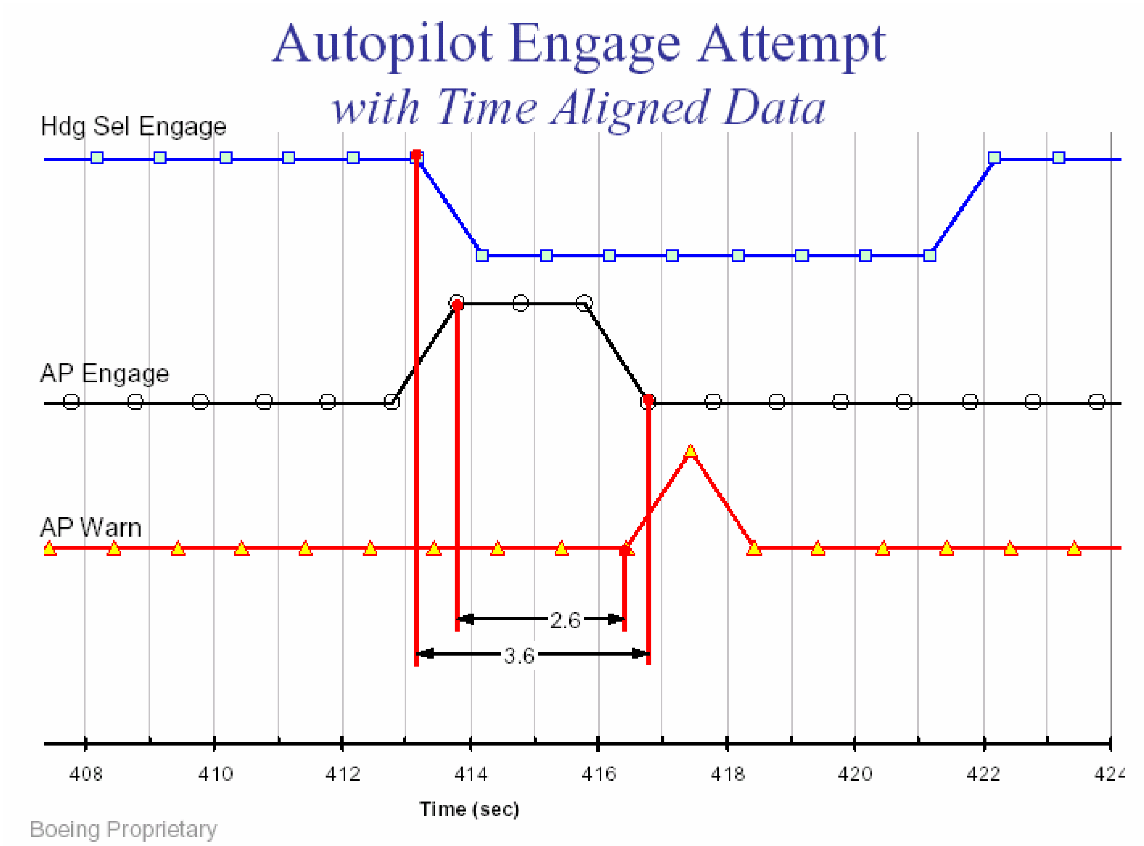
Any of the following conditions cause autopilot disengagement:

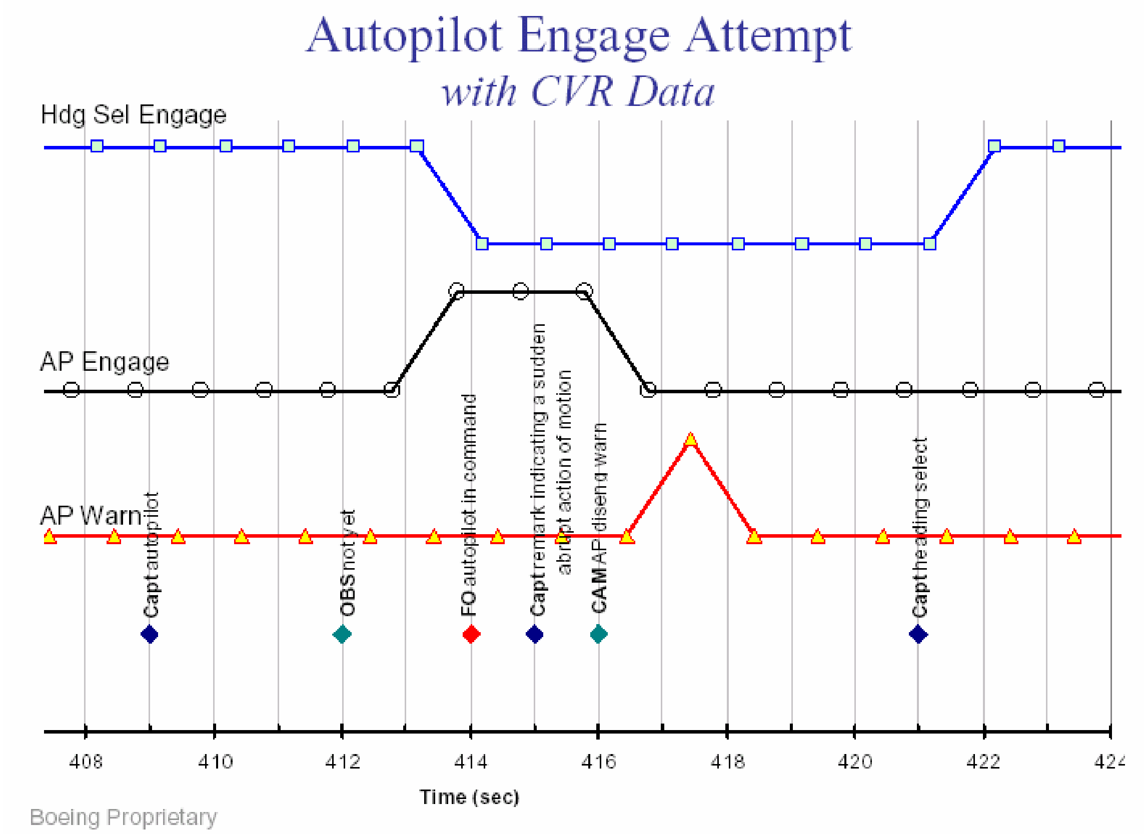
- Auto Stab Trim Cutout Switch in Cutout (status is not recorded in the FDR).
- Both Flap Switches and Stab Trim Motor don't agree as Flaps Up or as Flaps Down (switches status are not recorded in the FDR).
- Main Electric Trim Switch Activated (status is not recorded in the FDR).
- Aileron Force Limiter position does not agree with Flaps UP or Flaps Down
- CAS Invalid (status is not recorded in the FDR).
- Uncorrected Altitude Invalid (status is not recorded in the FDR).
- 26 VAC 400 Hz Invalid (status is not recorded in the FDR).
- MCP to FCC Bus Invalid (status is not recorded in the FDR).
- Pitch Angle Invalid (status is not recorded in the FDR).
- Pitch Rate Invalid (status is not recorded in the FDR).
- Roll Angle Invalid (status is not recorded in the FDR).
- Roll Rate Invalid (status is not recorded in the FDR).
- Baro Altitude Invalid (status is not recorded in the FDR).
- Elevator Detent Pressure Switch Indicates non-pressurized (status is not recorded in the FDR).
- Aileron Detent Pressure Switch Indicates non-pressurized (status is not recorded in the FDR).

C. Autopilot manually disconnected.

It is to be noted that the autopilot disconnect switches status on the control wheels horns are not recorded in the FDR.

2.5.10.2 Autopilot Disconnect Analysis (based on FDR and CVR available data):





The CVR statement "Not yet" is not attributed to the observer but to the Captain.

2.5.10.3 Probable conditions for autopilot disconnect:

1. Case of "Autopilot Engages but Disengages Approximately 3.6 seconds after Flight Crew Selects On"

   1.1 Manual Disconnect

   Warning length is consistent with "double click" typical of manual disconnects (within allowable warning duration tolerance). However, there is no disengagement callout by crew on CVR. In addition, the autopilot disconnect switches status on the control wheels horns are not recorded in the FDR.

   Note:

   - Boeing presentation (see 2.5.10.2) regarding autopilot function states that the duration of autopilot manual disconnect warning is less than 2 seconds
   - Honeywell verbal information, states the duration of autopilot manual disconnect warning is max of 3 seconds
   - Actual time of warning based on CVR is 2.136 seconds

   Although requested, Honeywell did not supply the investigation team with any supporting evidence.

   1.2 Automatic Disconnect

   A. Interlock invalid

   All interlocks were valid 3 sec earlier during autopilot engagement.

   This scenario requires one of the interlocks to become invalid during the 3 seconds and autopilot was engaged.

   B. Synchronization did not complete

   (FDR shows disconnect prior to min 3.695 seconds this scenario requires)

   B.1 Actuator never matches surface position

   B.2 Detent pressure sensed prior to detent command

   This condition presumes:

   - Detent solenoid stuck open prior to engagement attempt
   - Transfer valve jammed off center

   (Does not match FDR data as autopilot would disconnect within 182 ms)

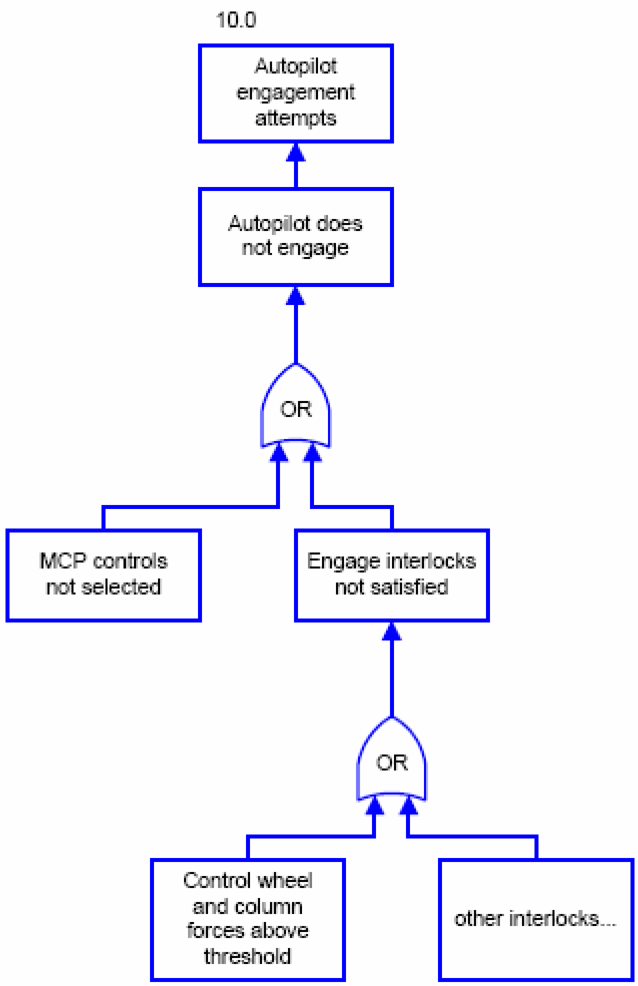
2. Case of Autopilot Does Not Engage[3]

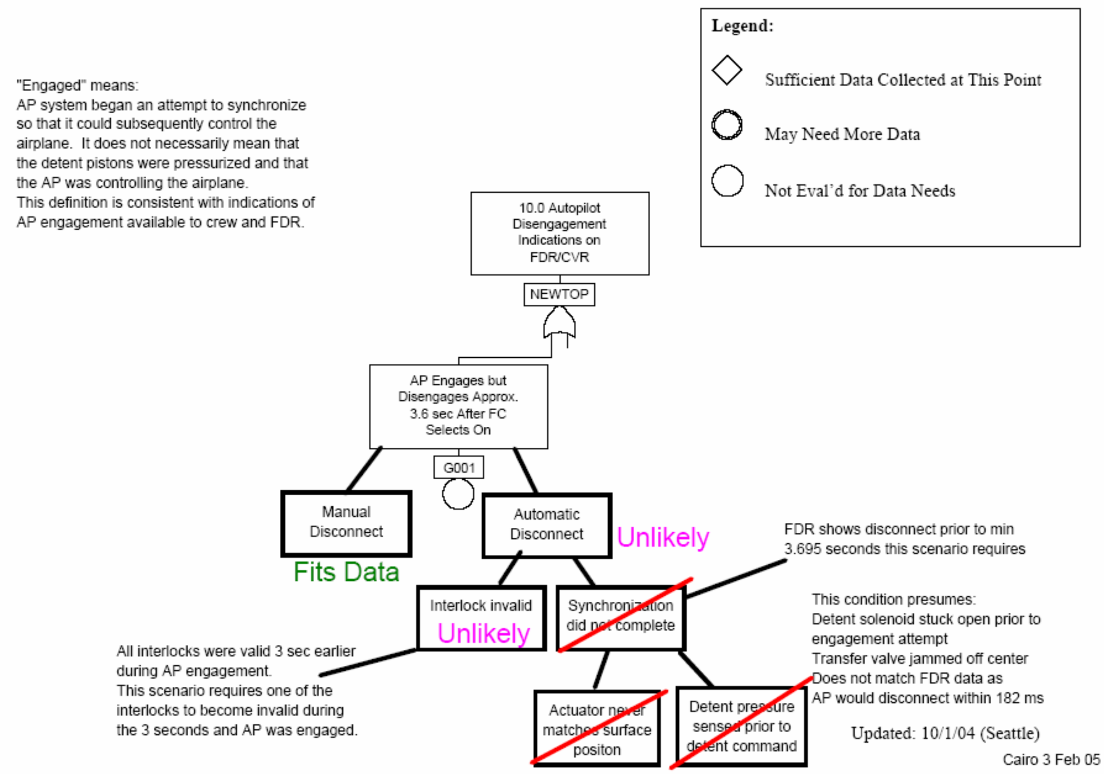
This case can be ruled out because the FDR shows that the autopilot did engage and the disconnect warning can be heard on the CVR.

Conclusion:

The investigation could not determine a higher possibility to any of the above findings (Autopilot automatically disengaged or manually disengaged), based on the given data.

[3] FDR shows status of autopilot engagement and disengagement. Cockpit indication and FDR indicate "Engaged" although the process of synchronization is still incomplete.


10.0
Autopilot engagement attempts
Autopilot does not engage
OR
MCP controls not selected
Engage interlocks not satisfied
OR
Control wheel and column forces above threshold
other interlocks...


Legend:
Sufficient Data Collected at This Point
May Need More Data
Not Eval'd for Data Needs
"Engaged" means:
AP system began an attempt to synchronize so that it could subsequently control the airplane. It does not necessarily mean that the detent pistons were pressurized and that the AP was controlling the airplane.
This definition is consistent with indications of AP engagement available to crew and FDR.
10.0 Autopilot Disengagement Indications on FDR/CVR
NEWTOP
AP Engages but Disengages Approx. 3.6 sec After FC Selects On
G001
Manual Disconnect
Fits Data
Automatic Disconnect
Unlikely
FDR shows disconnect prior to min 3.695 seconds this scenario requires
Interlock invalid
Unlikely
Synchronization did not complete
All interlocks were valid 3 sec earlier during AP engagement.
This scenario requires one of the interlocks to become invalid during the 3 seconds and AP was engaged.
This condition presumes:
Detent solenoid stuck open prior to engagement attempt
Transfer valve jammed off center
Does not match FDR data as AP would disconnect within 182 ms
Actuator never matches surface positon
Detent pressure sensed prior to detent command
Updated: 10/1/04 (Seattle)
Cairo 3 Feb 05

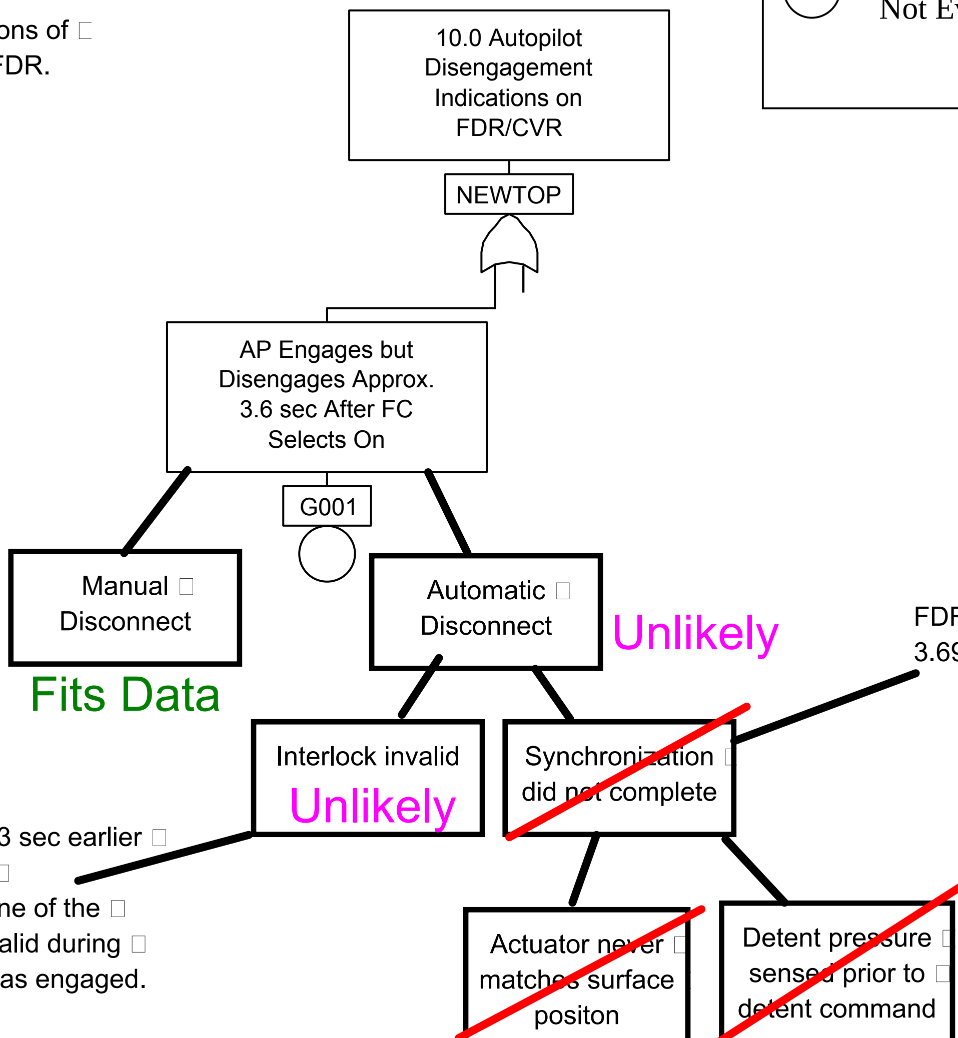
Legend:

◇ Sufficient Data Collected at This Point

◎ May Need More Data

○ Not Eval'd for Data Needs

"Engaged" means:
AP system began an attempt to synchronize so that it could subsequently control the airplane. It does not necessarily mean that the detent pistons were pressurized and that the AP was controlling the airplane.
This definition is consistent with indications of AP engagement available to crew and FDR.



FDR shows disconnect prior to min 3.695 seconds this scenario requires

All interlocks were valid 3 sec earlier during AP engagement.
This scenario requires one of the interlocks to become invalid during the 3 seconds and AP was engaged.

This condition presumes:
Detent solenoid stuck open prior to engagement attempt
Transfer valve jammed off center
Does not match FDR data as AP would disconnect within 182 ms

Updated: 10/1/04 (Seattle)

Cairo 3 Feb 05

2.5.11 Airplane begins roll to right

Based on the FDR data, the airplane stopped the left turn and started a right turn at about 92420

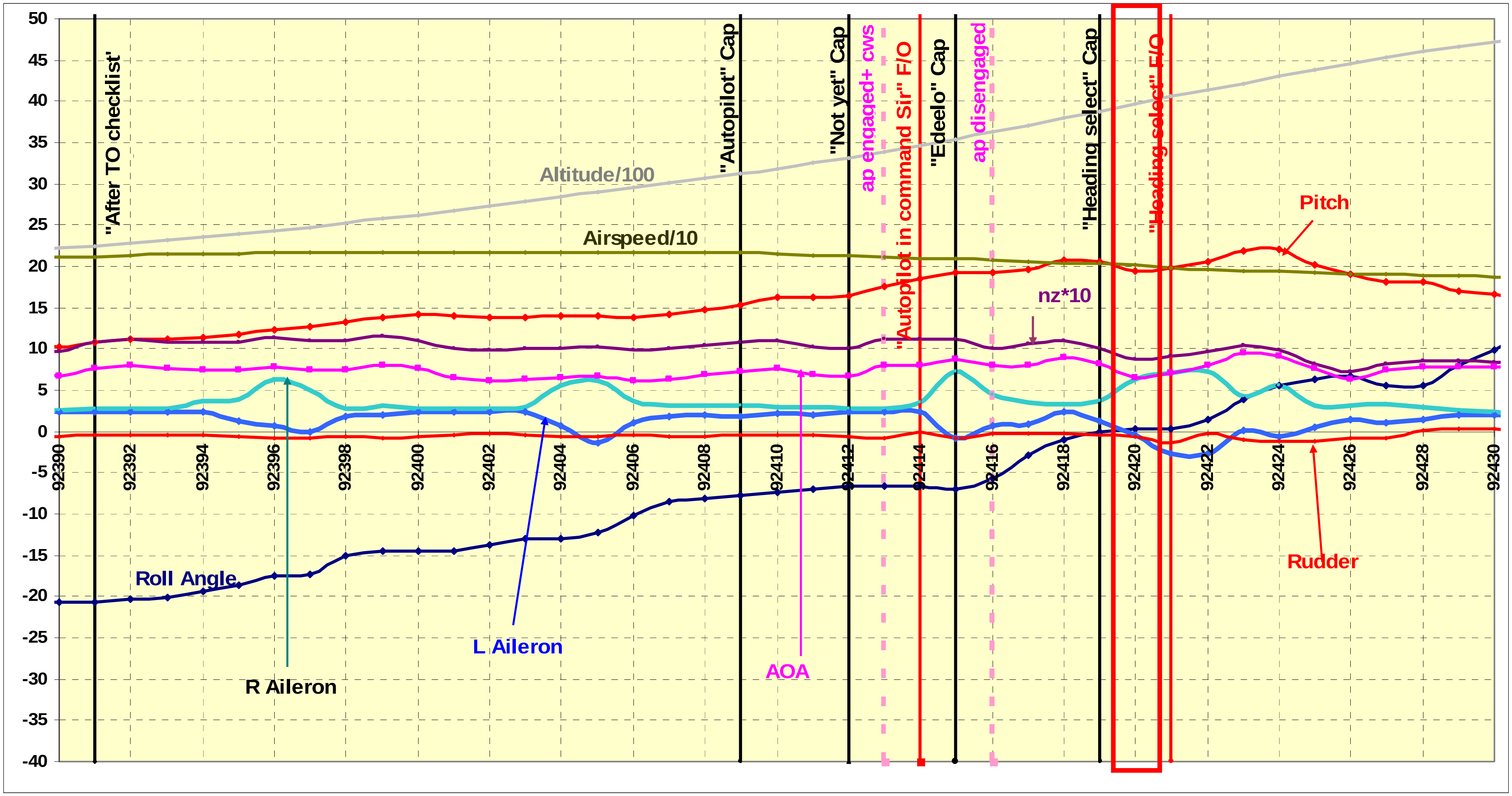


Figure 2.5.11.1 Airplane begins roll to right

2.5.11.1 Conditions which could lead to this event

A. NA

B- Flaps asymmetry:

The FDR did not show evidences of flap asymmetry. Based on these information, there is no evidence of flap asymmetry existing at the time of the event and consequently this condition could be ruled out

C- Slats asymmetry:

C.1 Uncommanded Deployment

Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

C.2 Remains Deployed (SLAT FULL DEPLOYED)

Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See section 2.5.13 Right roll continues to overbank with ailerons activities)

D- Thrust asymmetry:

With reference to section “2.3.6. Power plants”, it is shown that all the engines parameters were recorded in the FDR. However, some parameters data were not reliable (e.g. L engine N1). The other engines parameters are reliable including the N2 for both engines.. Based on these information, there is no evidence of thrust assymetry existed at the time of the event and consequently this condition could be ruled out

E- External Disturbance

This possibility could be ruled out based on FDR data, M- Cab Simulator Match to FDR and meteorogical data

F- Flight Crew Believes Autopilot is Engaged When it is not

Reference to FDR, CVR data and Crew Behavior studies, this condition could not be ruled out
CVR clearly records F/O announcement "Autopilot in command" on later "No autopilot commander". This strongly supports the above statement "F"

G- Lateral control system:

1- Pilot Input

1.1 Following FD
1.1.1 FD Commands Erroneous[1]
1.1.1.1Erroneous Heading
FDR records heading data used by FD - not erroneous. This condition could be ruled out
1.1.1.2 Erroneous Roll Data
FDR records roll data used by FD - not erroneous. This condition could be ruled out
1.1.1.3 Erroneous Selected Heading Data
Selected heading recorded on FDR, but only once every 64 seconds.
1.1.1.4 FD Computational Fault
Based on systems evaluation, this condition could be ruled out
1.1.1.5 Erroneous roll rate data
FDR records roll data used by FD - not erroneous
Correct roll data requires correct roll rate data.
This condition could be ruled out

1.1.2 FD Commands Correct
Unintended Direction of Selected Heading (to right of current heading)
1.1.2.1 Erroneous heading data to F/O EADI and F/O selects heading based on relative displacement to erroneous heading.
This condition could be ruled out

[1] Reference: Honeywell Presentation. 3-Feb-05. No FCC faults or combination of faults result in valid FDR data with erroneous commands.

1.1.2.2 Manual Input to MCP
This condition could be ruled out

1.1.2.3 Erroneous heading data to Captain EADI
CAPT heading data on FDR is accurate. This condition could be ruled out

1.2 Widening His Departure Pattern
N/A to this portion of flight. This condition could be ruled out

1.3 Mistaken Initial 140 Heading Interpretation
N/A to this portion of flight. This condition could be ruled out

1.4 To Level Wings Prior to Autopilot Engagement
N/A to this portion of flight. This condition could be ruled out

1.5 Following Erroneous EADI
FDR attitude data (same as left EADI data) is normal. EADI does not have failure modes which result in display of erroneous attitude data (with correct IRU input). This condition could be ruled out

1.6 Reaction to Uncommanded Roll
From the performance point of view; the FDR match w.r.t external disturbance. External disturbance is inconsistent with FDR/ Performance data. This condition could be ruled out

1.7 Pilot Loses Situational Awareness
See Section 2.6.1 Crew Behavior Subcommittee, this condition could not be ruled out

2- Autopilot Initiated

2.1 Commanded
Based on FDR, this condition could be ruled out

2.2 Uncommanded (actuator faults only)
(See section 2.5.13 Right roll continues to overbank with ailerons activities, item 6.2.2.3.1 Actuator Hardover without Force Limiter 17 to 20 lb Force)
This condition could not be ruled out.

3- Lateral System Fault

3.1 Jam

3.1.1 Between Wheel and PCU
(FDR showed ailerons movements in both directions (both ailerons)

Performance; FDR Match)
These conditions could be ruled out

3.1.2 Between PCU and Aileron
(FDR showed ailerons movements in both directions (both ailerons)
Performance; FDR Match)
These conditions could be ruled out

3.2 PCU Fault
This condition could be ruled out (Systems Evaluation)
See Appendix 2-1 lateral control analysis.
This condition could be ruled out

3.3 Cable Break
3.3.1 Between Wheel and PCU
(FDR showed ailerons movements in both directions (both ailerons)
Performance; FDR Match)
These conditions could be ruled out

3.3.2 Between PCU and Aileron
(FDR showed ailerons movements in both directions (both ailerons)
Performance; FDR Match)
These conditions could be ruled out

3.4 Trim/Feel Unit Fault
This condition could not be ruled out
(See Section 2.5.13 Right roll continues to overbank with ailerons activities, item 6.3.4 Trim/Feel Unit Fault.)

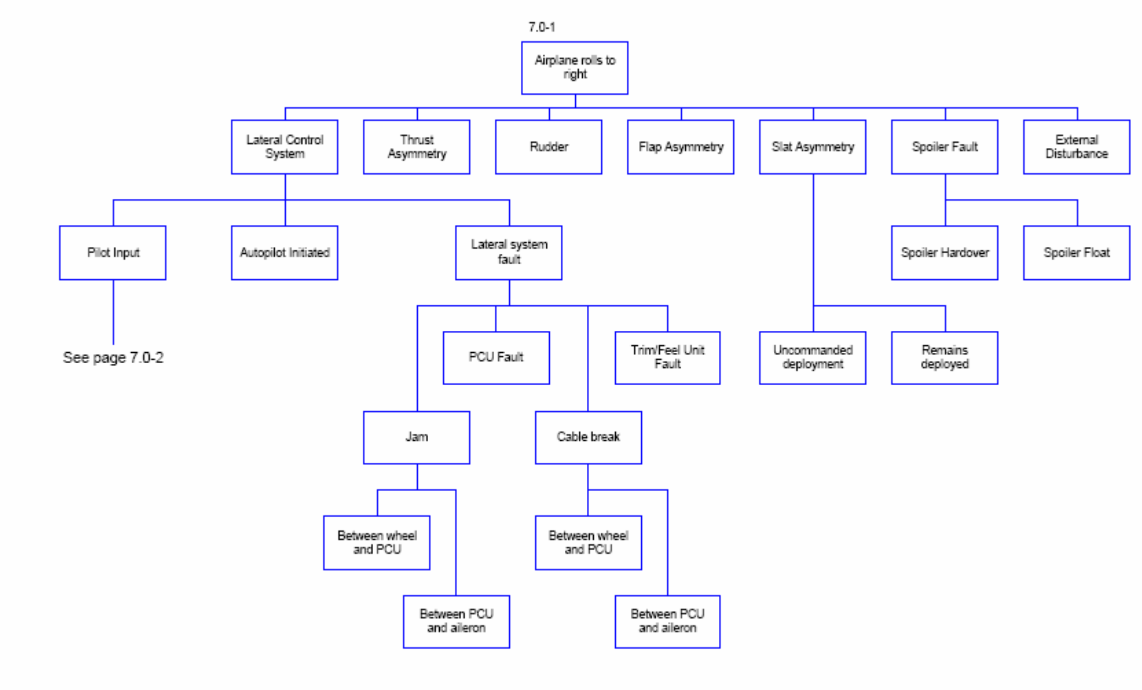
3.5 Spoiler Fault

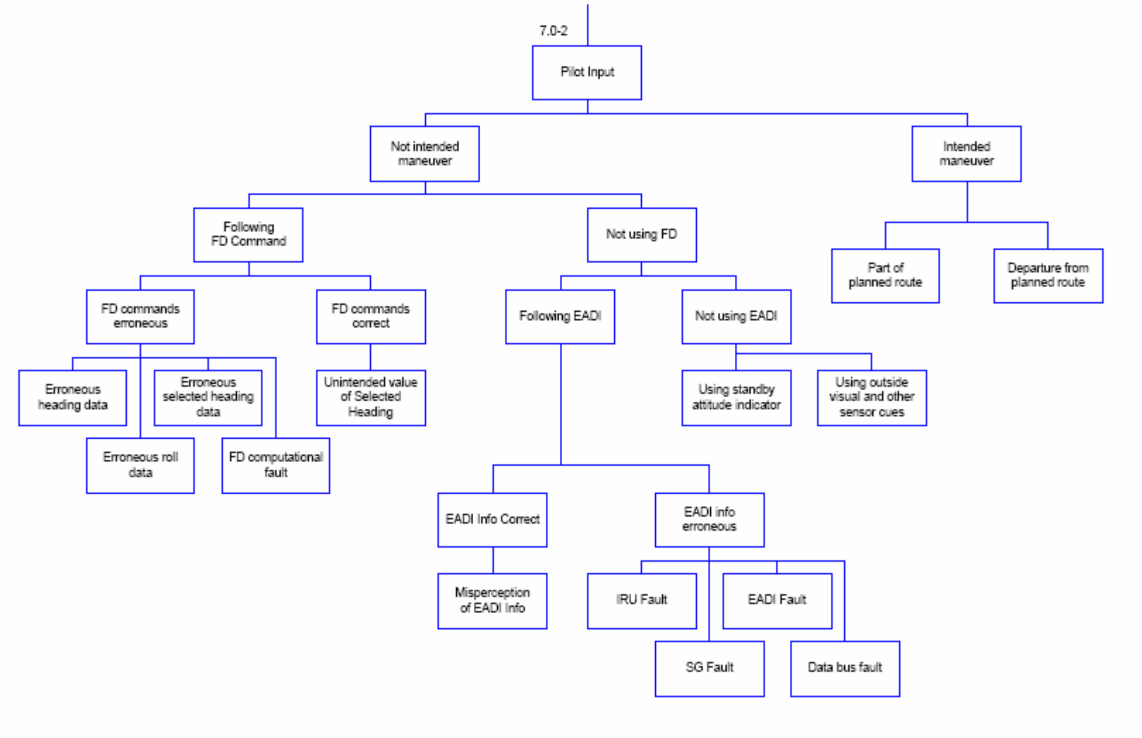
3.5.1 Spoiler Hardover
These conditions could be ruled out based on M-Cab results
See Section 2.5.13 Right roll continues to overbank with ailerons activities, item 6.3.5 Spoiler Fault

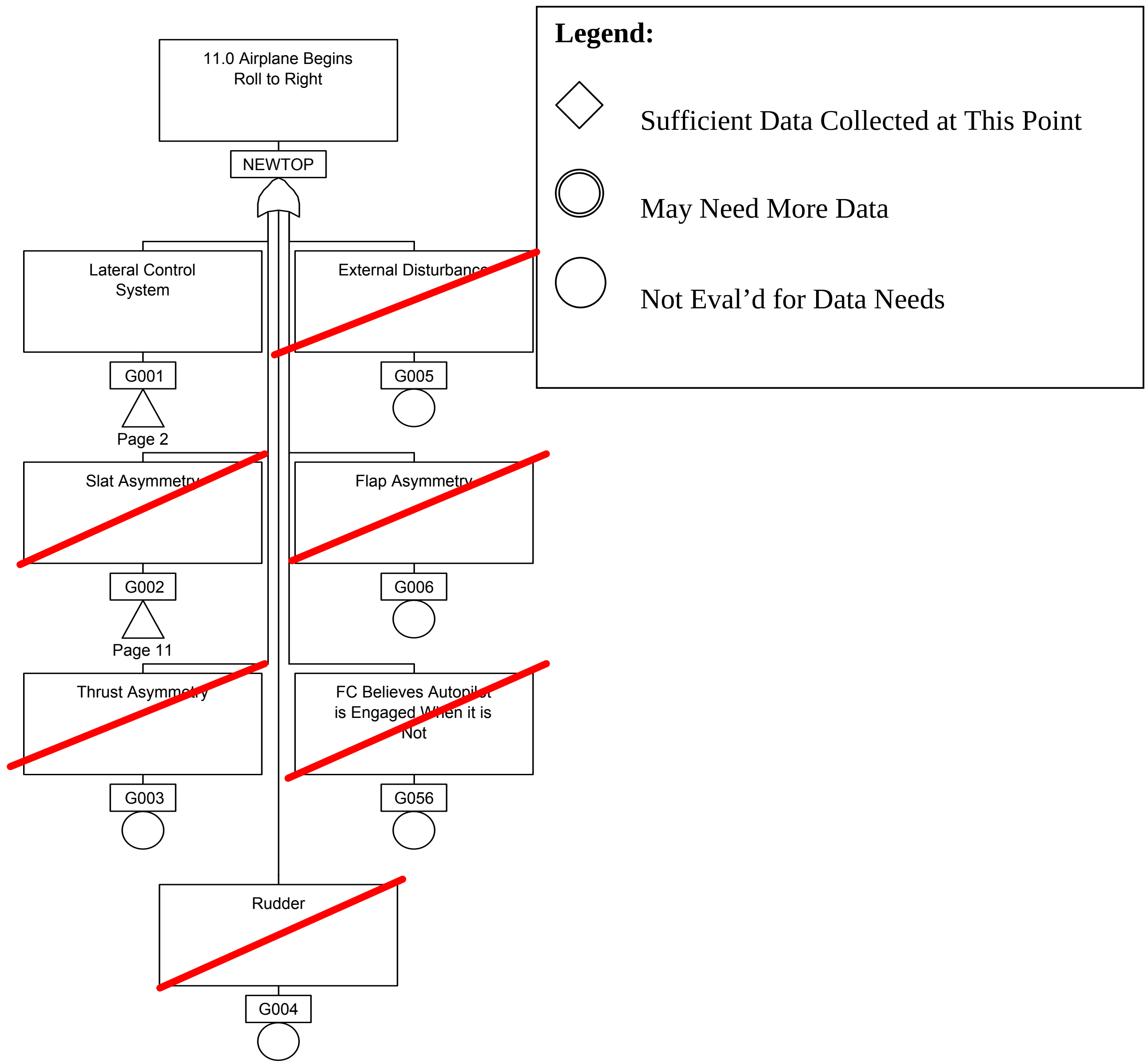
3.5.2 Spoiler Float
These conditions could be ruled out based on M-Cab results
See Section 2.5.13 Right roll continues to overbank with ailerons activities, item 6.3.5 Spoiler Fault

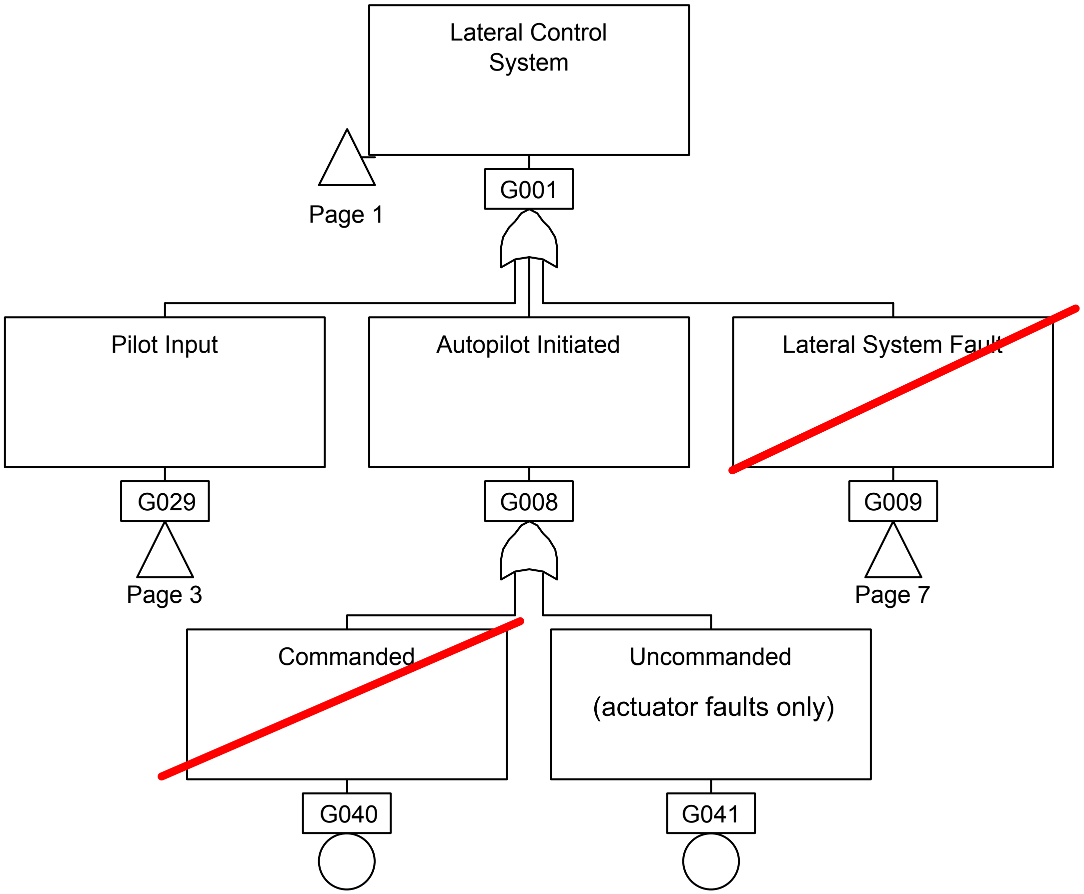
Conclusion

After completing the process of elimination of the unlikely conditions shown above, the investigation could not determine a higher possibility to any of the above findings based on the given data.

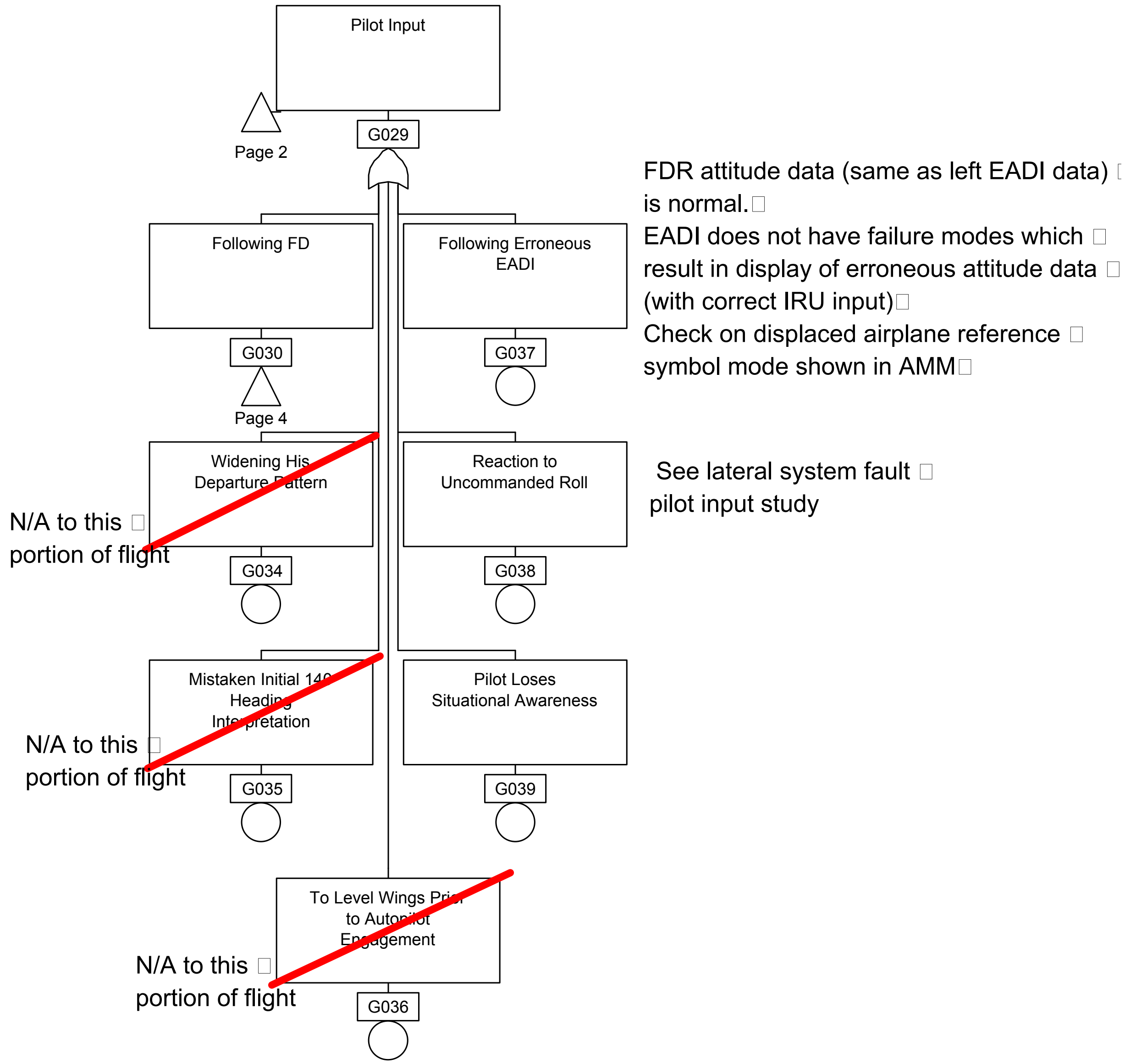

7.0-1
Airplane rolls to right
Lateral Control System
Thrust Asymmetry
Rudder
Flap Asymmetry
Slat Asymmetry
Spoiler Fault
External Disturbance
Pilot Input
Autopilot Initiated
Lateral system fault
Spoiler Hardover
Spoiler Float
See page 7.0-2
PCU Fault
Trim/Feel Unit Fault
Uncommanded deployment
Remains deployed
Jam
Cable break
Between wheel and PCU
Between wheel and PCU
Between PCU and aileron
Between PCU and aileron

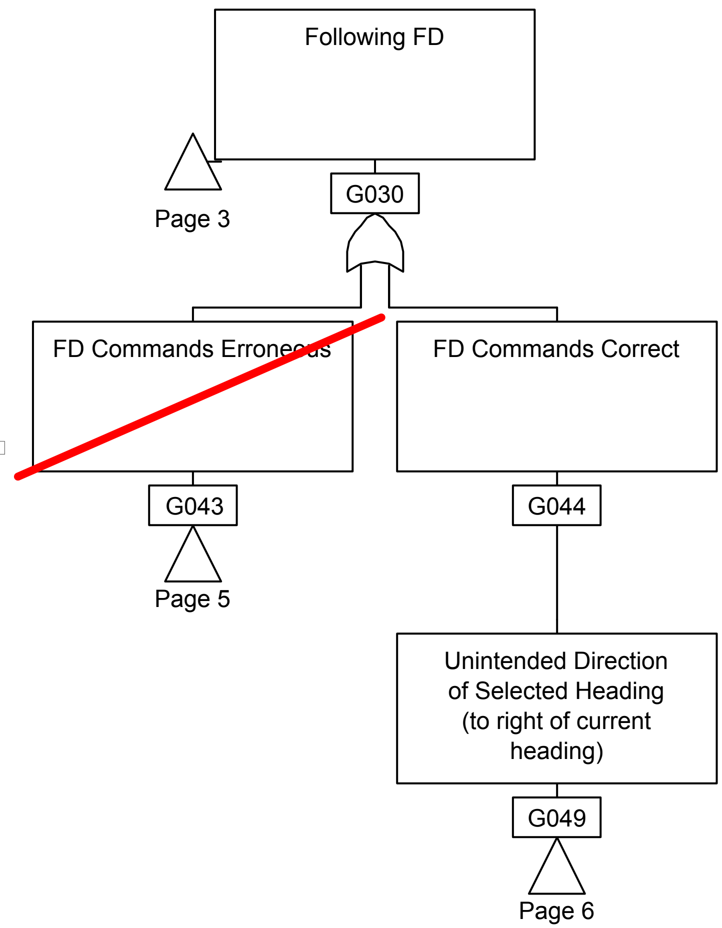

7.0-2
Pilot Input
Not intended maneuver
Intended maneuver
Following FD Command
Not using FD
Part of planned route
Departure from planned route
FD commands erroneous
FD commands correct
Following EADI
Not using EADI
Erroneous heading data
Erroneous selected heading data
Unintended value of Selected Heading
Using standby attitude indicator
Using outside visual and other sensor cues
Erroneous roll data
FD computational fault
EADI Info Correct
EADI info erroneous
Misperception of EADI Info
IRU Fault
EADI Fault
SG Fault
Data bus fault


11.0 Airplane Begins Roll to Right
NEWTOP
Lateral Control System
G001
Page 2
External Disturbance
G005
Slat Asymmetry
G002
Page 11
Flap Asymmetry
G006
Thrust Asymmetry
G003
FC Believes Autopilot is Engaged When it is Not
G056
Rudder
G004
Legend:
Sufficient Data Collected at This Point
May Need More Data
Not Eval'd for Data Needs

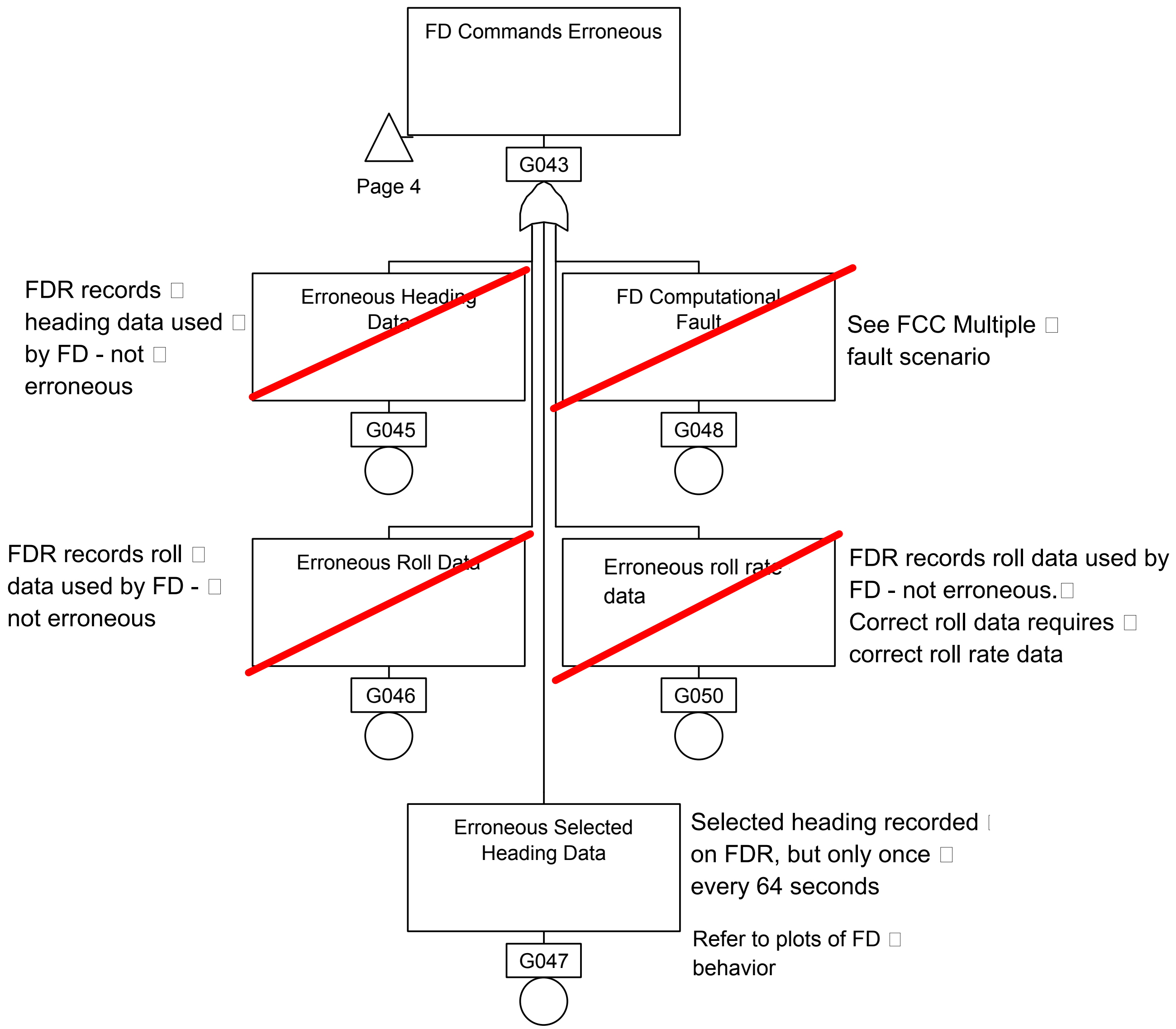


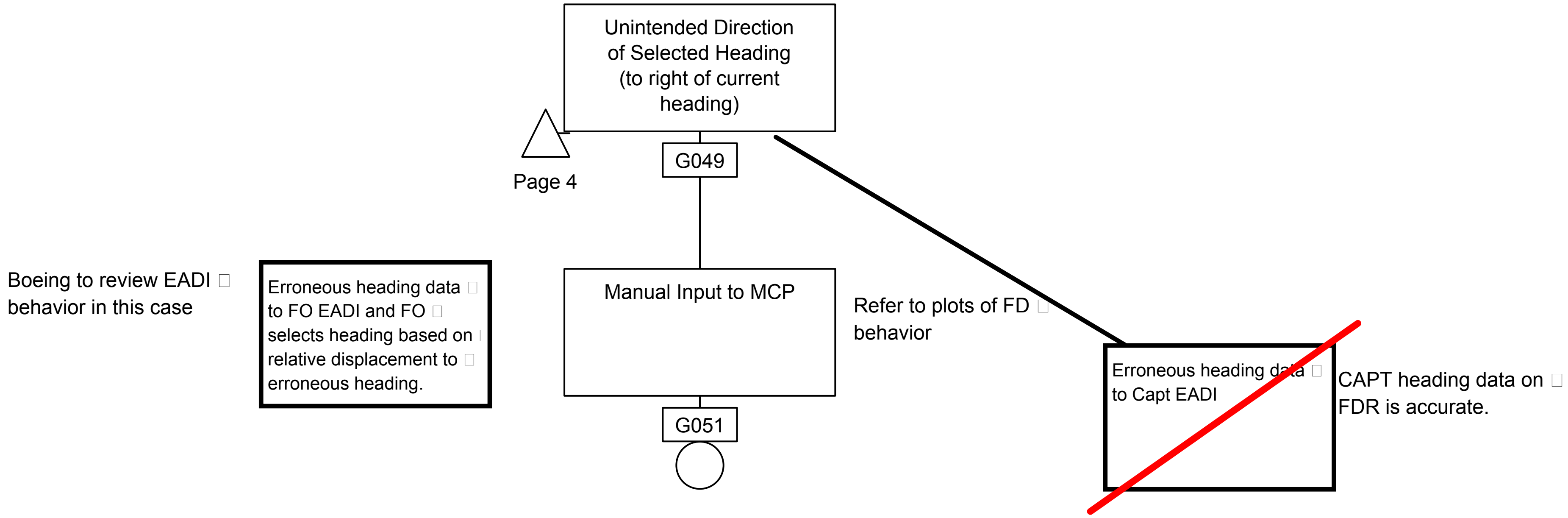
Lateral Control System
Page 1
G001
Pilot Input
Autopilot Initiated
Lateral System Fault
G029
Page 3
G008
G009
Page 7
Commanded
Uncommanded
(actuator faults only)
G040
G041


Pilot Input
Page 2
G029
FDR attitude data (same as left EADI data) is normal.
EADI does not have failure modes which result in display of erroneous attitude data (with correct IRU input)
Check on displaced airplane reference symbol mode shown in AMM
Following FD
G030
Page 4
Following Erroneous EADI
G037
Widening His Departure Pattern
N/A to this portion of flight
G034
Reaction to Uncommanded Roll
See lateral system fault pilot input study
G038
Mistaken Initial 140 Heading Interpretation
N/A to this portion of flight
G035
Pilot Loses Situational Awareness
G039
To Level Wings Prior to Autopilot Engagement
N/A to this portion of flight
G036

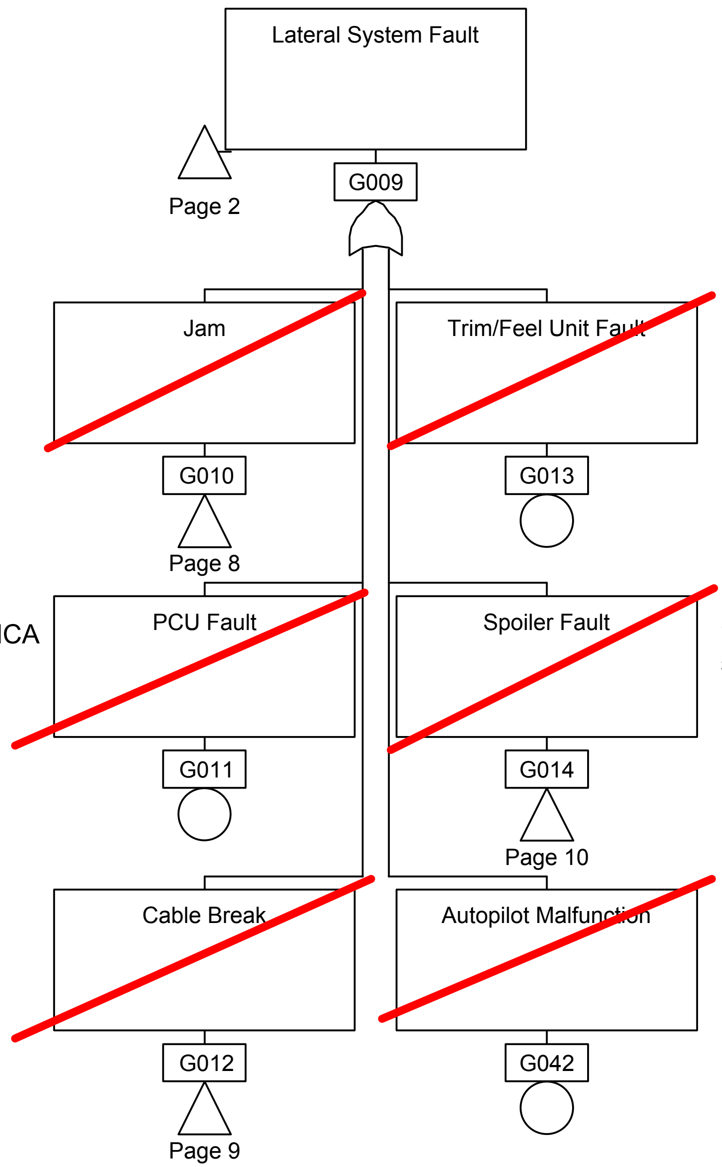


See Honeywell Presentation. 3 Feb 05
No FCC faults or combination of faults
result in valid FDR data wtih erroneous
commands.


FD Commands Erroneous
Page 4
G043
FDR records heading data used by FD - not erroneous
Erroneous Heading Data
G045
FD Computational Fault
G048
See FCC Multiple fault scenario
FDR records roll data used by FD - not erroneous
Erroneous Roll Data
G046
Erroneous roll rate data
G050
FDR records roll data used by FD - not erroneous.
Correct roll data requires correct roll rate data
Erroneous Selected Heading Data
G047
Selected heading recorded on FDR, but only once every 64 seconds
Refer to plots of FD behavior

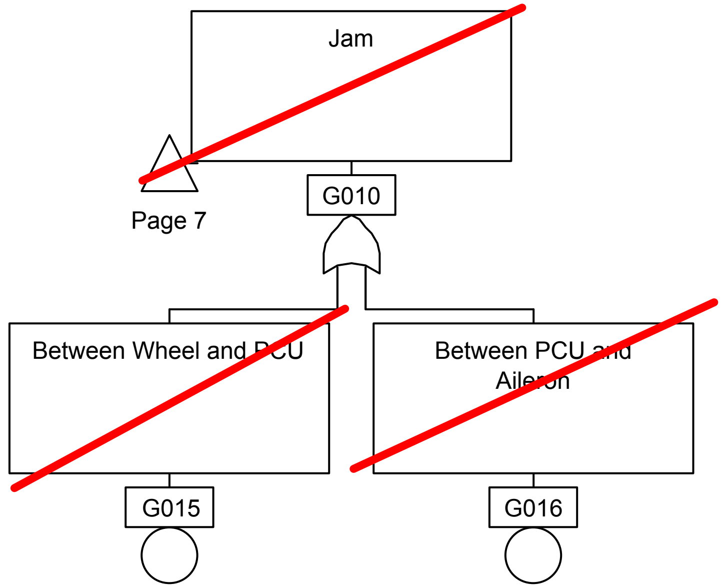


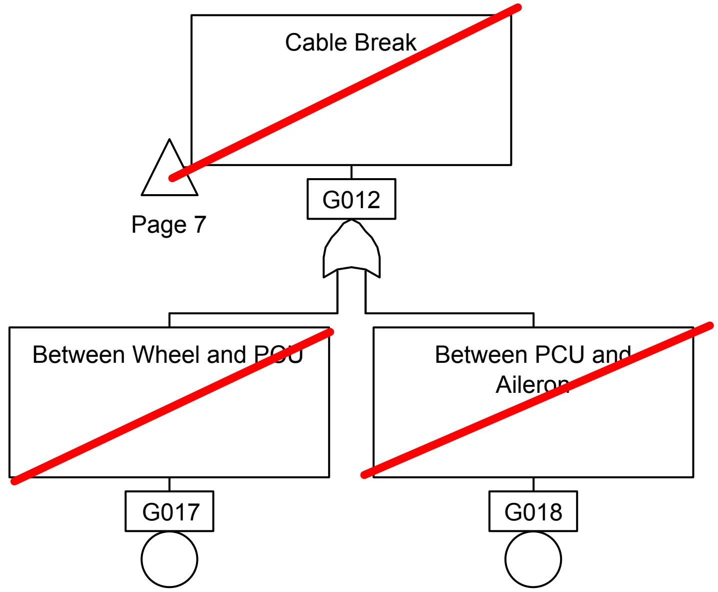
Unintended Direction of Selected Heading (to right of current heading)
G049
Page 4
Boeing to review EADI behavior in this case
Erroneous heading data to FO EADI and FO selects heading based on relative displacement to erroneous heading.
Manual Input to MCP
G051
Refer to plots of FD behavior
Erroneous heading data to Capt EADI
CAPT heading data on FDR is accurate.

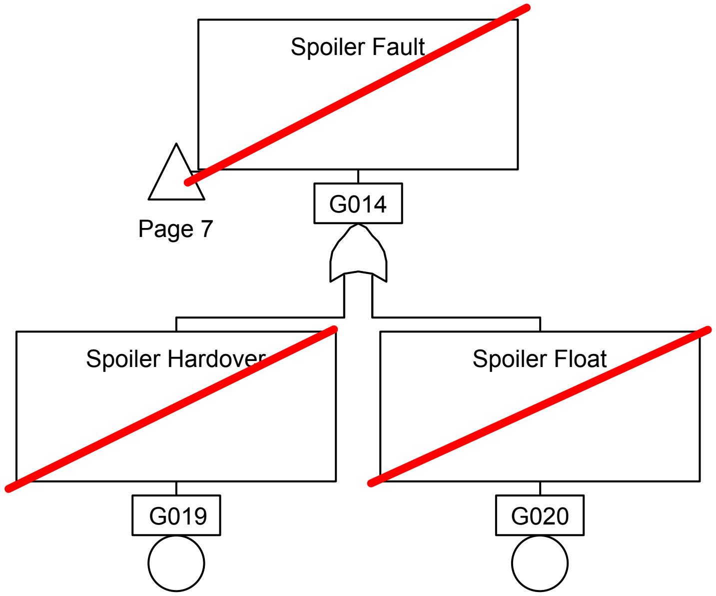


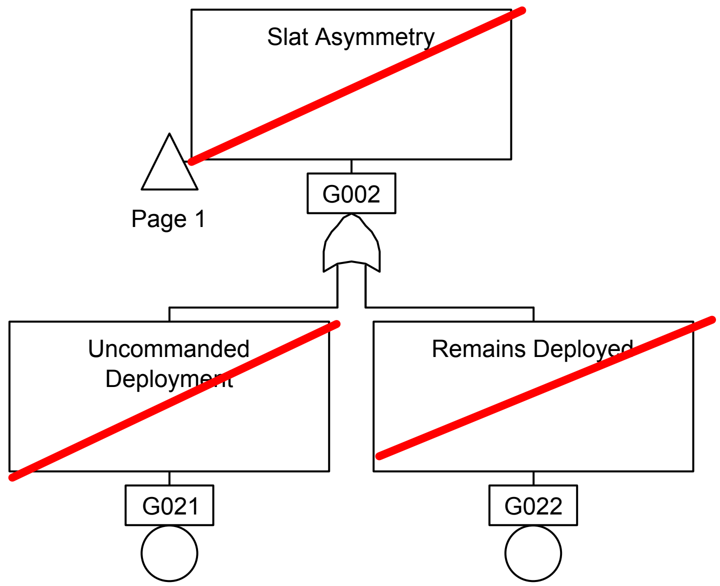
Closed pending MCA review

Closed pending MCA review of simulation results from cable jam resulting in faired spoilers.


Jam
Page 7
G010
Between Wheel and PCU
Between PCU and Aileron
G015
G016


Cable Break
Page 7
G012
Between Wheel and PCU
Between PCU and Aileron
G017
G018


Spoiler Fault
Page 7
G014
Spoiler Hardover
Spoiler Float
G019
G020


Slat Asymmetry
Page 1
G002
Uncommanded Deployment
Remains Deployed
G021
G022

2.5.12 Heading Select engaged

- At time 02:44:05 (92419), the Captain requested “heading select”.

- At time 02:44:07 (92421), the F/O states "heading select" and the FDR records heading select mode engaging.

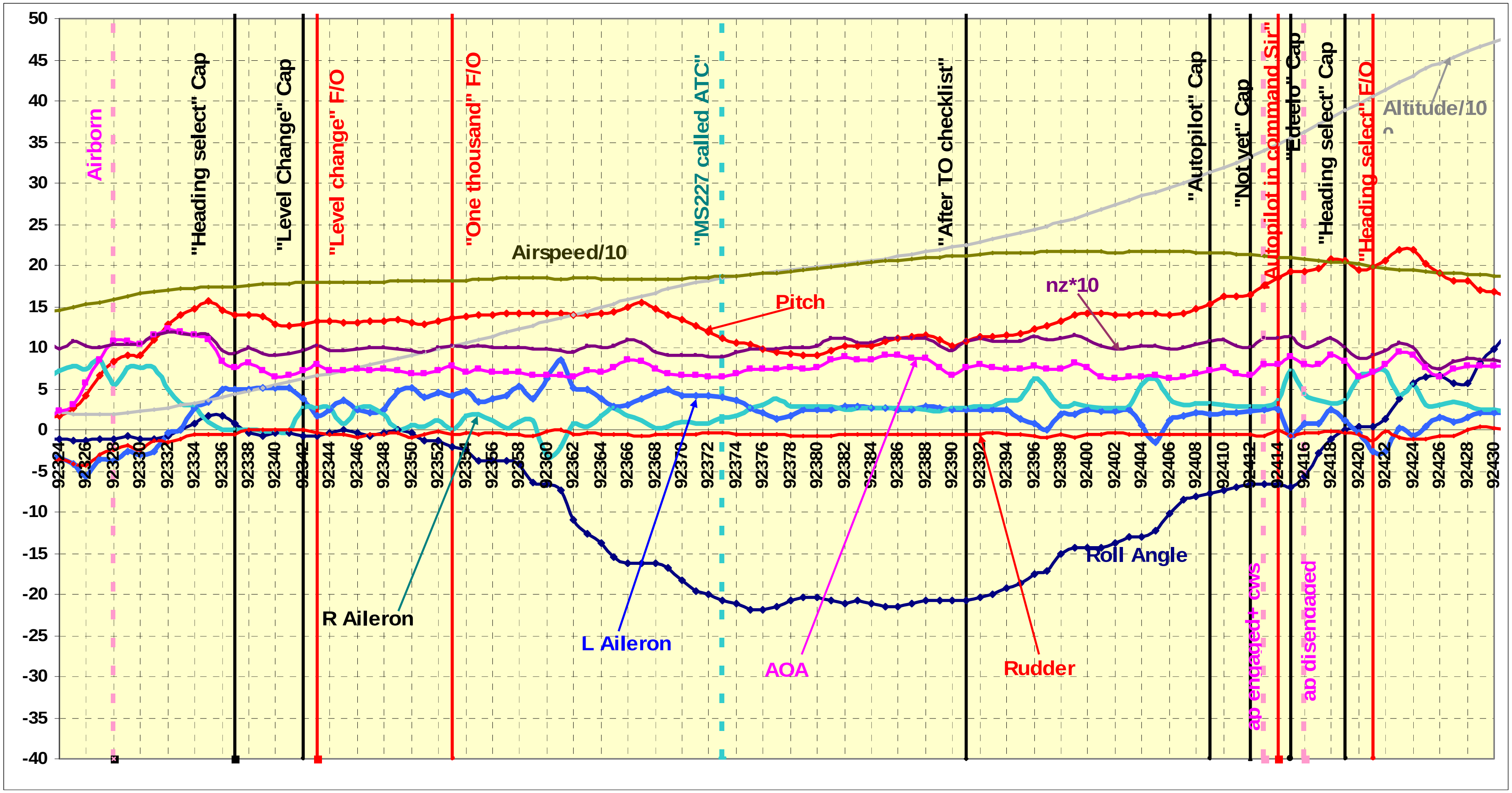


Figure 2.5.12.1 Heading Select engaged

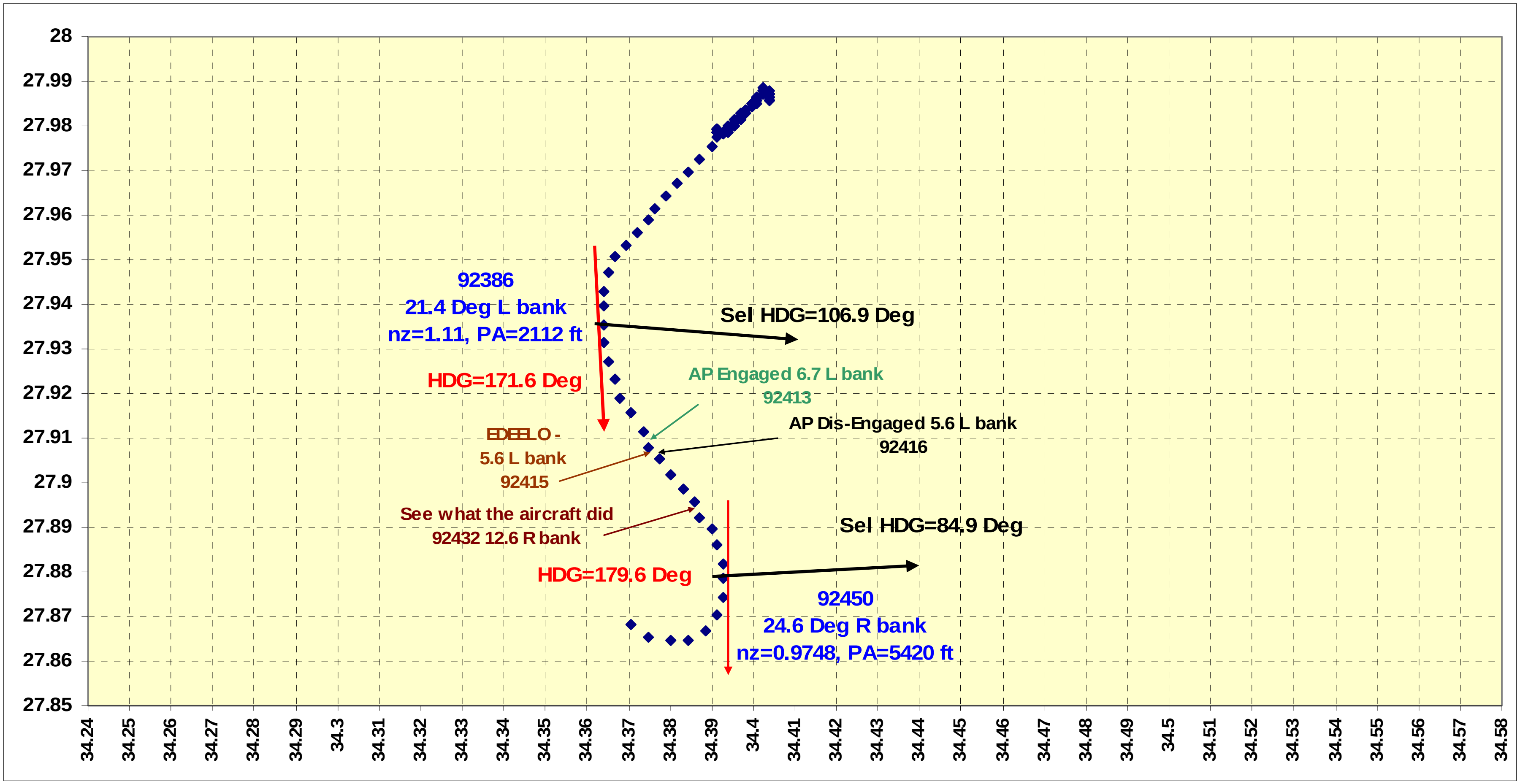


Figure 2.5.12.2 Heading Select (FDR, CVR)

Heading Select engaged might be engaged as a result of the following:

- Manual selection

  (Supported by CVR informatio)

2.5.13 Right roll continues to overbank with ailerons activities

Based on the FDR and the CVR data, the airplane continued the right overbank until a maximum of 111 degree at about 92472.

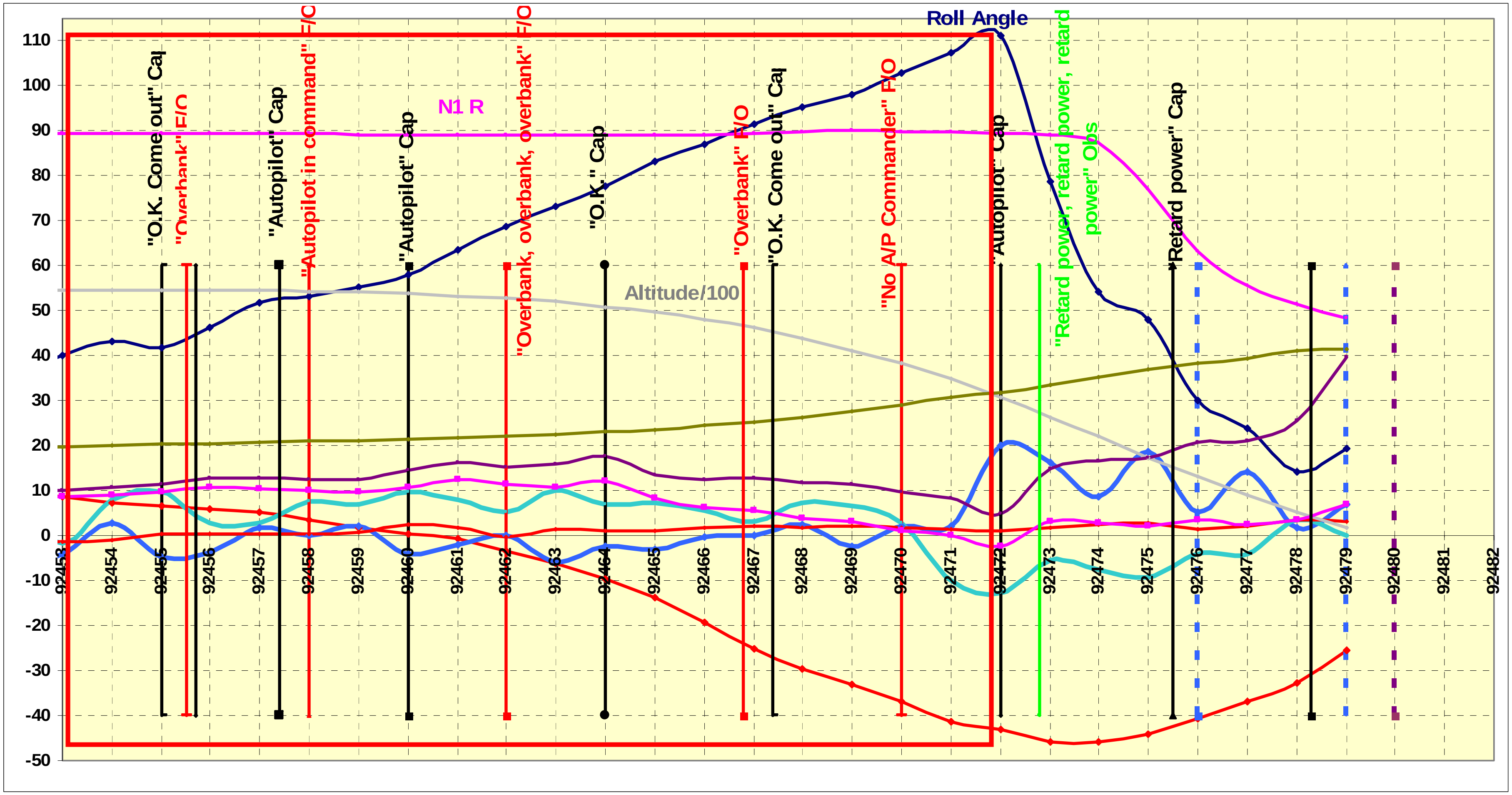


Figure 2.5.13.1a Right roll continues to overbank with ailerons activities

The conditions which may lead to the event are presented in the following:

1. Slat Asymmetry
    1.1 Uncommanded Deployment

    Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See following M-Cab results figures)

    1.2 Remains Deployed (SLAT FULL DEPLOYED)

    Based on the performance evaluation, M-Cab results (Simulation match to FDR) this condition could be ruled out. (See following M-Cab results figures)

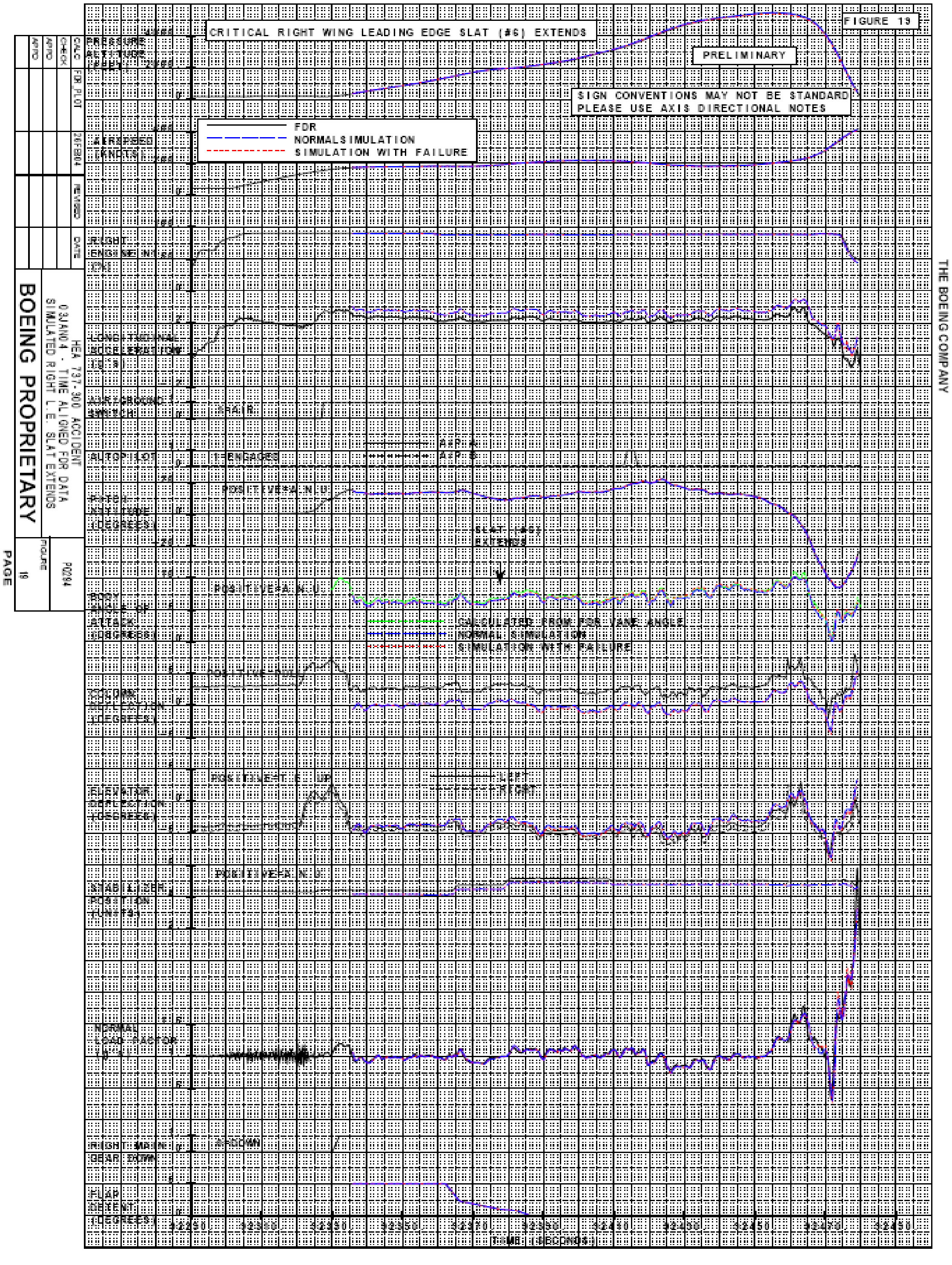


Figure 2.5.13.2a Critical right L.E. Failure- Slat #6 extends (longitudinal)

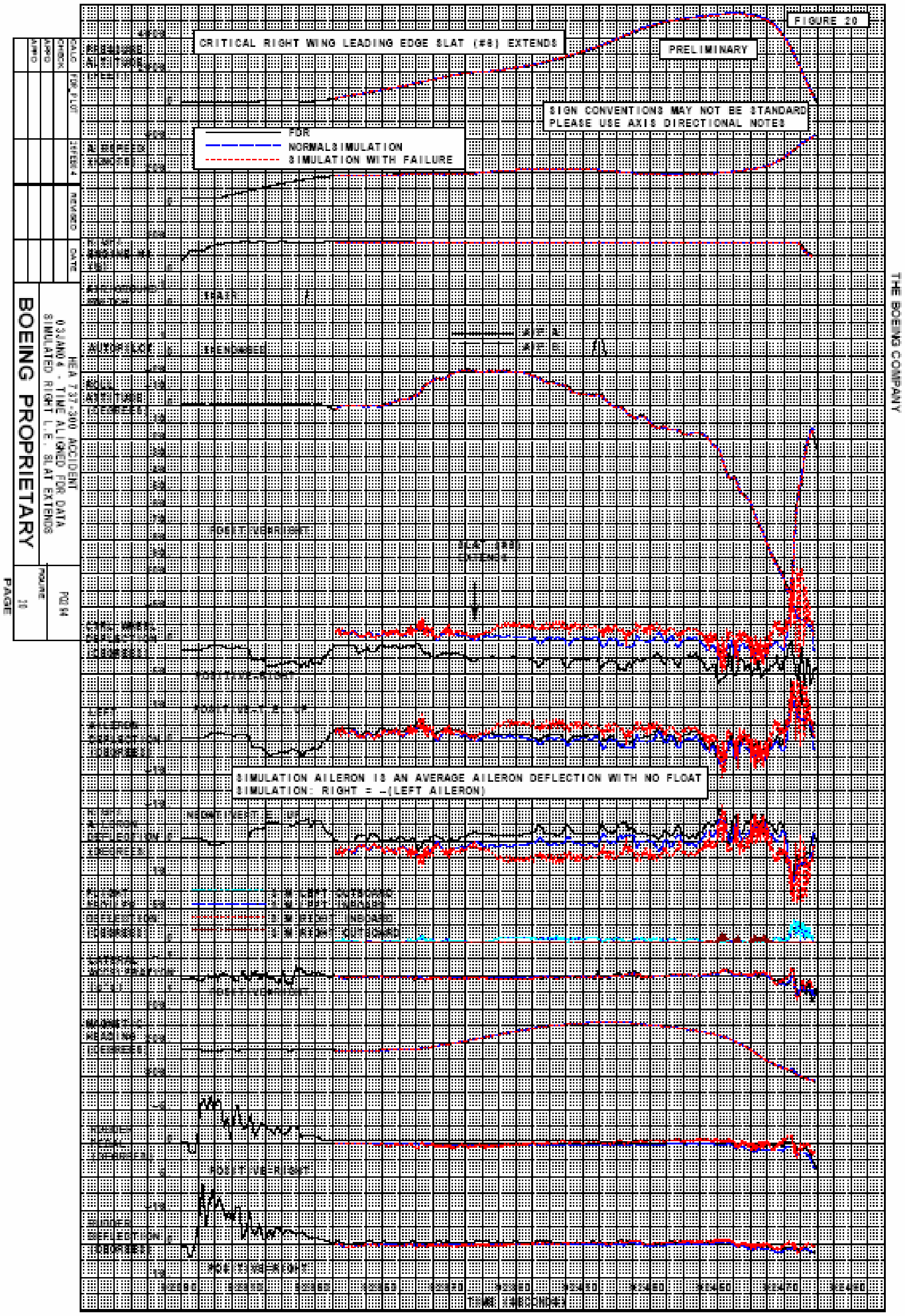


Figure 2.5.13.2b Critical right L.E. Failure- Slat #6 extends (lateral)

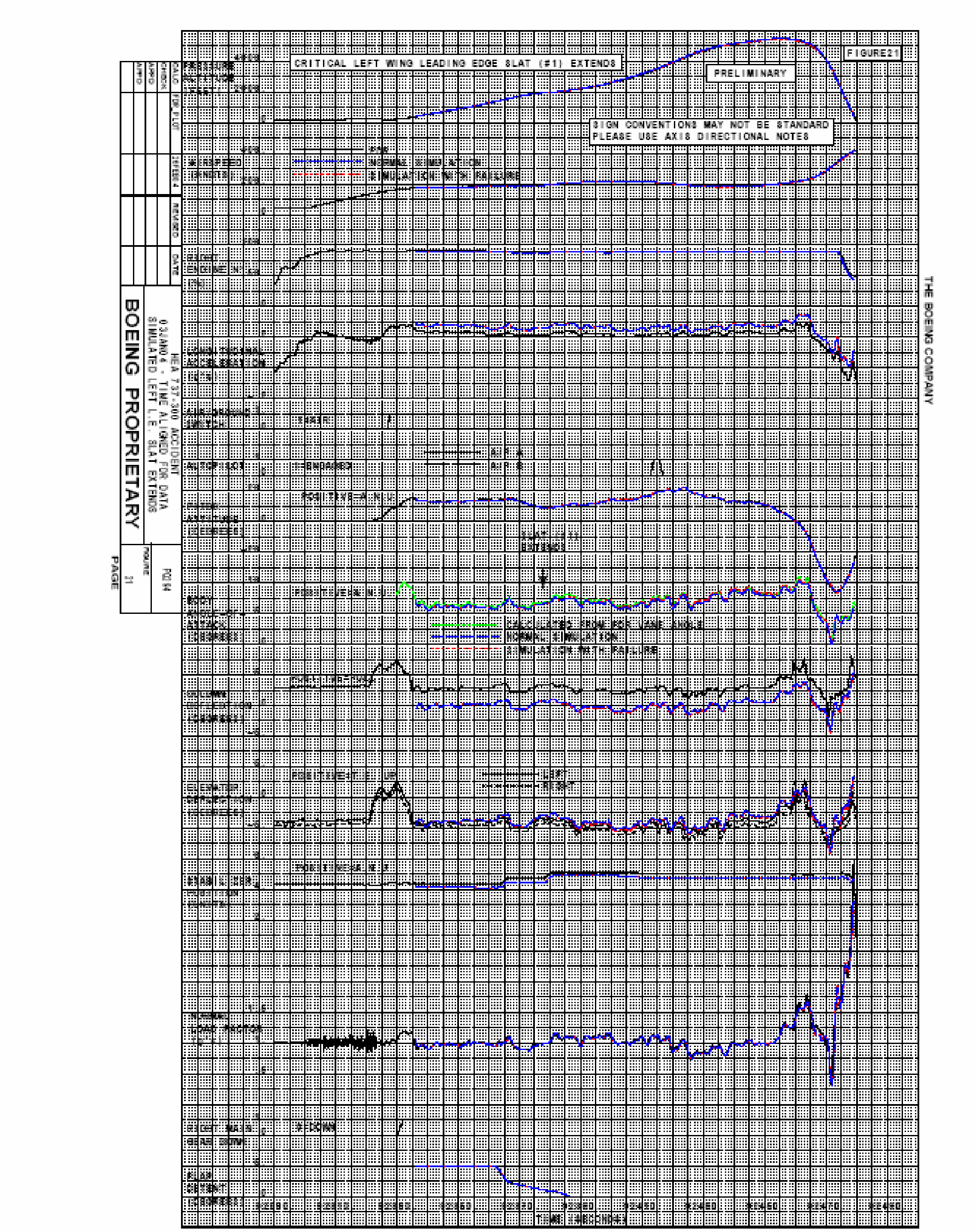


Figure 2.5.13.3a Critical left L.E. Failure- Slat #1 extends (longitudinal)

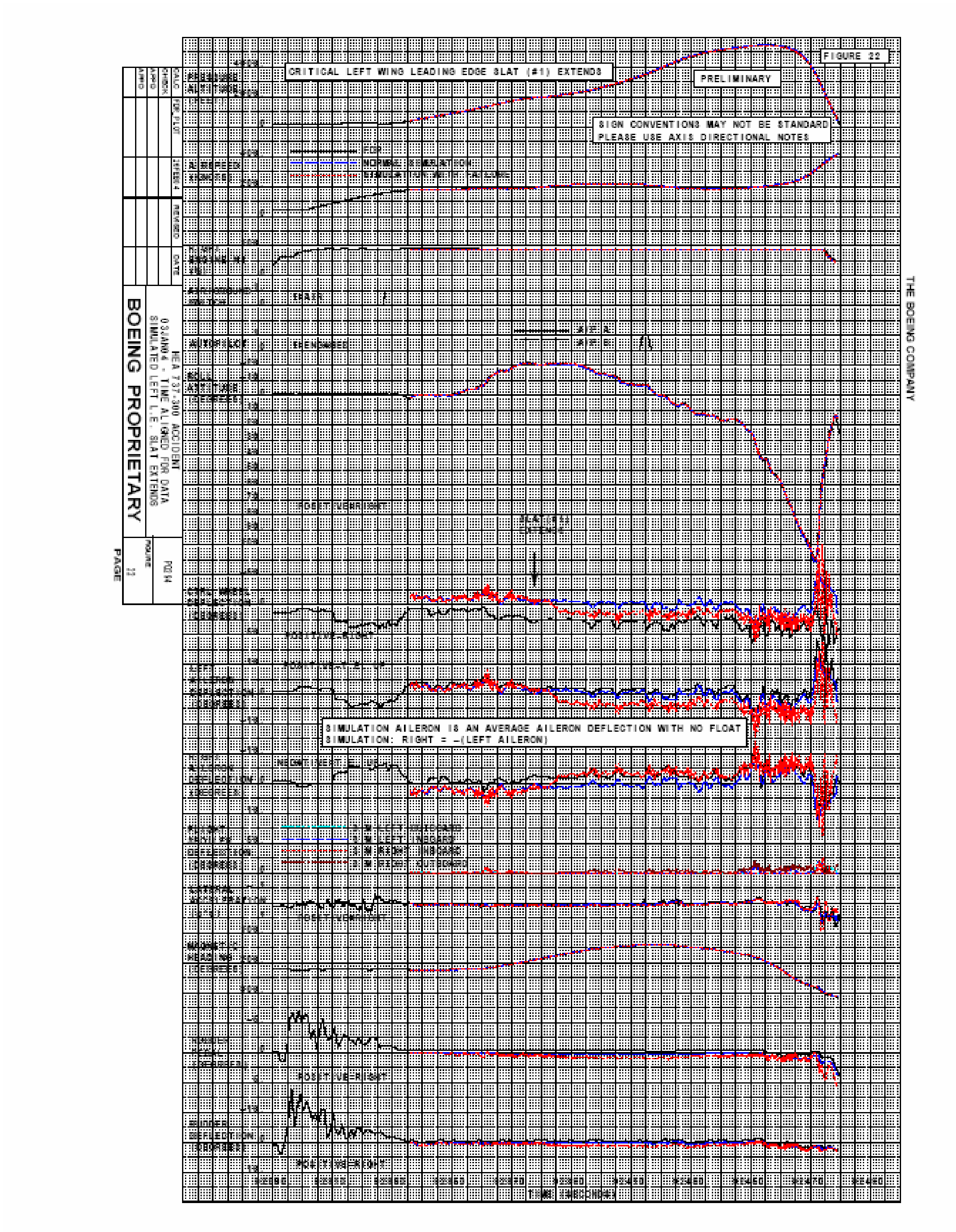


Figure 2.5.13.3b Critical left L.E. Failure- Slat #1 extends (lateral)

2. Thrust Asymmetry

With reference to section “2.3.6. Power plants”, it is shown that all the engines parameters were recorded in the FDR. However, some parameters data were not reliable (e.g. L engine N1). The other engines parameters are reliable including the N2 for both engines.. Based on these information, there is no evidence of thrust assymetry existing at the time of the event and consequently this condition could be ruled out

3. NA

4. External Disturbance

This condition could be ruled out based on FDR data, M- Cab Simulator Match to FDR and meteorogical data

5. Flap Asymmetry

The FDR did not show evidences of flap asymmetry. Based on these information, there is no evidence of flap asymmetry existing at the time of the event and consequently this condition could be ruled out

6. Lateral Control System

6.1 Flight Crew Behavior

6.1.1 Pilot Input

6.1.1.1 Following FD

6.1.1.1.1 FD Commands Erroneous

6.1.1.1.1.1 Erroneous Heading Data
This condition will not command past bank angle limit, thus this condition could be ruled out

6.1.1.1.1.2 Erroneous Roll Data
(L IRU roll data on FDR is correct), , thus this condition could be ruled out

6.1.1.1.1.3 FD Computational Fault; FCC computer fault
Based of the analysis of the A/P faults, this condition could be ruled out

6.1.1.1.1.4 Erroneous Roll Rate Data
L IRU roll data on FDR is correct; therefore roll rate data must be accurate.
(Supported by M-Cab test results), thus this condition could be ruled out

6.1.1.1.1.5 Erroneous Selected Heading Data
This condition will not command past bank angle limit. Supported by system evaluation; (Supported by M-Cab test results), thus this condition could be ruled out

6.1.1.1.2 FD Commands Correct

6.1.1.1.2.1 Unintended Direction of Selected HDG (to right of current HDG)

6.1.1.1.2.1.1 Manual Input to MCP
FD would not command overbank if correct. (Supported by System Evaluation; M-Cab test results), thus this condition could be ruled out

6.1.1.2 Following Erroneous EADI

6.1.1.2.1 Captain EADI Erroneous

6.1.1.2.1.1 Erroneous Attitude Data from IRU
L IRU data is correct on FDR,
(Supported by system evaluation;
FDR data common), thus this
condition could be ruled out

6.1.1.2.1.2 Symbol Generator Fault

6.1.1.2.1.2.1 Blanking; SG Fail
Based on System Evaluation, no
indication would occur, thus this
condition could be ruled out

6.1.1.2.1.2.2 Offset Airplane Reference
Based on systems
evaluation, this condition
could be ruled out

6.1.1.2.2 Alternate Instruments Not Cross-Checked

No information was available to exclude this condition, therefore this condition could not be ruled out

6.1.1.3 Reaction to Uncommanded Roll (pilot interaction with fault)
From the performance point of view; the FDR match with respect to external disturbance. External disturbance is inconsistent with FDR/ Performance data, this condition could be ruled out

6.1.1.4 Pilot Loses Situational Awareness

6.1.1.4.1 Captain experiences SD Type II

Based on the outcome of the Crew Behavior Subcommittee studies, this condition could not be ruled out

6.1.1.4.2 Captain misinterprets ADI indications

See Section 2.6 Crew Behavior

6.2 Autopilot Initiated

6.2.1 Commanded

6.2.1.1 CWS-R

Autopilot does not command past bank angle limit. Therefore this condition will not cause overbank. (Supported by M-Cab evaluation), thus this condition could be ruled out

6.2.1.2 All Other Modes

Autopilot does not command past bank angle limit. Therefore does not cause overbank. (Supported by Systems Evaluation; FDR Data), thus this condition could be ruled out

(It is to be noted that the A/P does not command past bank angle limit. Therefore this condition will not cause overbank).

6.2.2 Autopilot Malfunction

6.2.2.1 FCC Fault

6.2.2.1.1 Failure of Bank Angle Limit Function

No FCC internal faults can lead to autopilot engagement or erroneous commands FCC Fault Monitoring Disconnected, thus this condition could be ruled out[1]

6.2.2.1.2 Other FCC Internal Faults

No FCC internal faults can lead to autopilot engagement or erroneous commands FCC Fault Monitoring Disconnected, thus this condition could be ruled out (see footnote #1)

6.2.2.2 MCP Fault (SCENARIO 9 10A, 10B, 10C Erroneous Selected Heading)

This scenario requires:
Autopilot failure to engaged state but outputting disengaged status data to FDR
FDR Bank data-fault does not affect bank angle limits
Thus this condition could be ruled out

6.2.2.3 Autopilot Actuator Fault

[1] According to information supplied by Honeywell

6.2.2.3.1 Actuator Hardover without Force Limiter 17 to 20 lb Force

6.2.2.3.1.1 Both Solenoids and Transfer Valve Jammed (Autopilot actuator, both Solenoids and Transfer Valve Jammed (Actuator Hardover without Force Limiter 17 to 20 lb Force))

(Refer to appendix 2-1 lateral control analysis, Table 3 Hypothetical failures scenarios [Autopilot Actuator], Scenario 4)

Assumptions:

- These faults require 3 concurrent faults. Detent solenoid was in correct position at autopilot engagement. Arm solenoid could be latent failure. Transfer was working on previous flight and could have occurred anytime after last use of autopilot and would have been latent from that point.
- Both the Arm and the Detent solenoid are assumed to fail (stuck open). The transfer valve is assumed to fail in the position commanding right bank

The cause of these failures can not be conclusively identified. However the failure of the arm solenoid (stuck open solenoid) might have been the result of a stuck closed contact (MCP engage relay A). Also these failures might be the result of an electric short within the electrical socket on the autopilot actuator.

Consequences of the hypothetical failures:

- This triple fault will result in an A/P actuator hardover.
- The autopilot can not be engaged.

- Detent pressure switch will sense hydraulic pressure before engagement; therefore, the pre-engagement logic will not be valid preventing engagement of autopilot.
- With autopilot disengaged, both aileron wheels will be driven away of the neutral position and will be positioned at about 60 degrees wheel position (Refer to figure 2.5.13.5, forces versus wheels position)
- The ailerons and flight spoilers will follow movement of the ailerons control wheels.
- The affected autopilot actuator will always try to drive the ailerons and spoilers towards the actuator hardover position
- The authority of the autopilot is shown in Figure ".5.13.5 "Ailerons and spoilers behavior with autopilot actuator hardover"
- The Captain will be able to control the ailerons and flight spoilers with an additional force of 17 lbs to overcome detent piston pressure and override the autopilot actuator.
- Whenever the control wheels are released, the control wheel will tend to return to the relevant autopilot actuator hardover position (60 degrees wheel position), resulting in an aileron deflection of about ± 13 degrees and spoilers deflection.
- This fault will not be associated with any visual or audio warning in the cockpit

This condition could not be ruled out, based on the following:

- The results obtained from the analytical studies and the M-Cab test show a very close consistency with the available data.
- With reference to FDR data and after autopilot disconnect, the FDR shows tendency for the ailerons to move towards right turn direction. Movement of the aileron surfaces as shown in the FDR towards the neutral

position could be explained by crew attempts to control the airplane attitude with the existence of the failure. The rate of airplane rolling to the right is always reduced with these attempts. The forces required to move the ailerons by the captain are higher than the forces required in normal condition with no fault.

- Whenever the control wheels are released, the ailerons move towards the offset position showing high consistency with the fault existence. The fault was continually driving the airplane towards more right roll
- The movements of the ailerons throughout the last recovery phase highly support this scenario. The FDR data shows that even with the captain attempt to recover the airplane at the last stages, the ailerons always had the trend to move towards the opposite direction of correction which is highly consistent with the fault existence when the captain effort to restore the airplane is reduced.

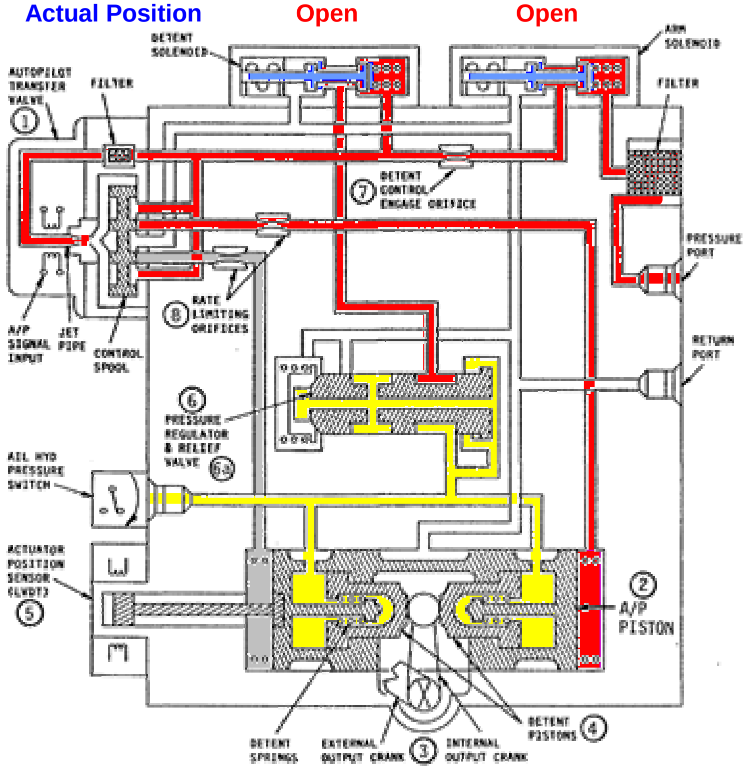
Therefore, it could be concluded that this hypothetical condition shows close consistency with the event. This condition is also consistent with the possibility of recovering the airplane when appropriate quantity of input is applied timely on the airplane (M- Cab tests).

(See also section 2.6 Crew Behavior)
This condition could not be ruled out

Scenario 12d – Both Solenoids Stuck Open with Transfer Valve Jammed

Solenoid Valve	Detent	Arm
Command	Closed	Closed
Actual Position	Open	Open

This triple fault will result in an A/P actuator hardover. The force limit of the actuator still operates normally.



- Hyd System Pressure
- Mod Piston Command Pressure
- Detent Piston Reduced Pressure
- Return Pressure

Figure 2.5.13.4 Autopilot Actuator

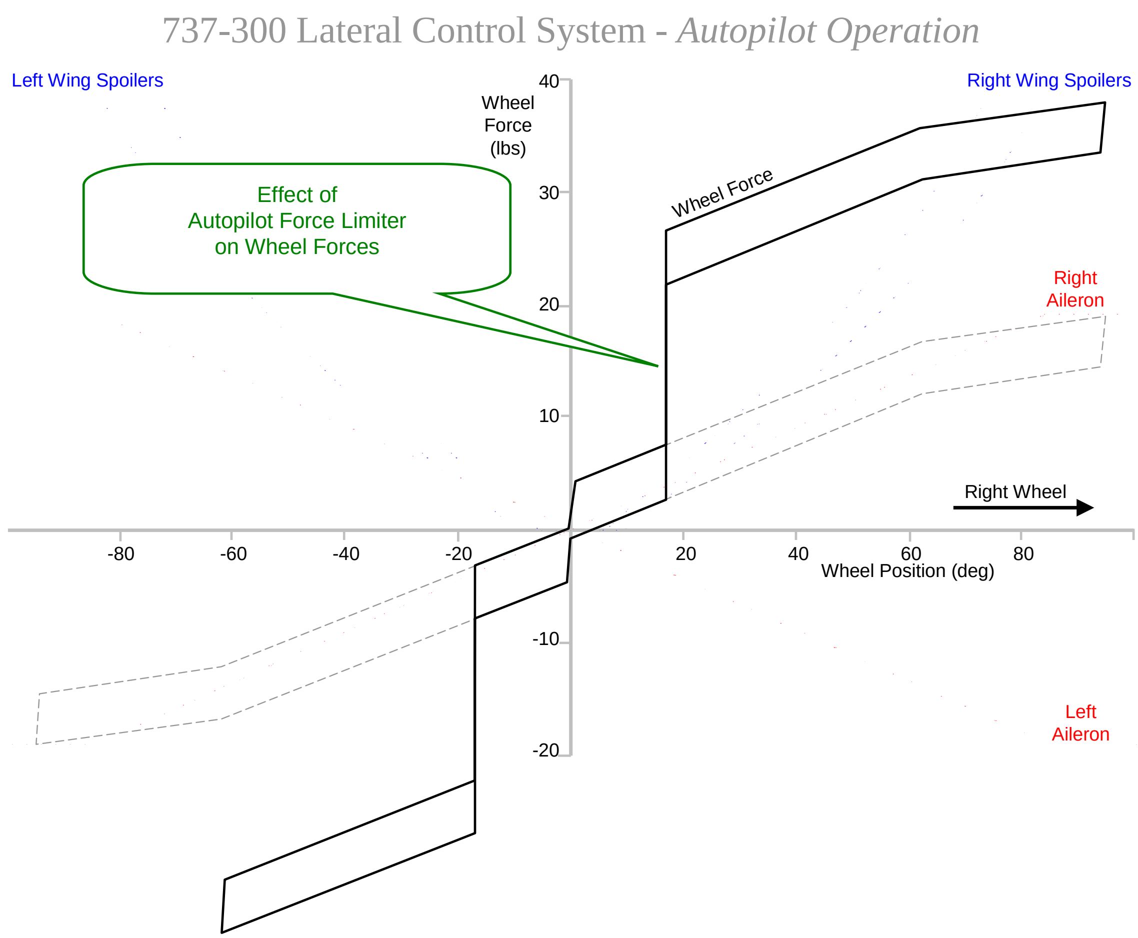


Figure 2.5.13.5 Ailerons and spoilers behavior with autopilot actuator hardover

6.2.2.3.1.2 Both Solenoids, Transfer Valve, and Pressure Regulator Jammed

Inconsistent, based on M-Cab results and systems evaluation, thus this condition could be ruled out

6.2.2.3.1.3 Both Solenoids, Transfer Valve, and Relief Valve Jammed

Inconsistent, based on M-Cab results and systems evaluation, thus this condition could be ruled out

6.2.2.3.2 Actuator Hardover with 80 lb Force

6.2.2.3.2.1 Both Solenoids, Transfer Valve, Pressure Regulator, and Relief Valve

Fighting 80 lbs of wheel force is a significant effort which prohibits normal breathing/ speech patterns (inconsistent with CVR data), thus this condition could be ruled out

6.2.2.3.2.2 Shearout Does Not Break

Fighting 80 lbs of wheel force is a significant effort which prohibits normal breathing/ speech patterns (inconsistent with CVR data), thus this condition could be ruled out

6.2.2.3.3 No Autopilot Input to Lateral Control System (Latent Fault)

6.2.2.3.3.1 Arm Solenoid Stuck Open

Based on system evaluation, this fault is latent and does not cause any anomalous system operation. (having no lateral system input).

6.2.2.3.3.2 Detent Solenoid Stuck Open

(Sys Evaluation; this fault has no lateral system input)

Based on system evaluation, this fault is latent and does not cause any anomalous system operation. (having no lateral system input).

6.2.2.3.4 Additional 17 lb Centering Force on CW, Arm and Detent Solenoid Stuck Open (SCENARIO 12C)

This fault causes an increase in centering force, but does not create any tendency for right roll, thus this condition could be ruled out

6.2.2.4 Sensor Faults

6.2.2.4.1 Spoiler Sensor Fault

This scenario requires:
Autopilot failed to “engaged" state but outputting disengaged status data to FDR (System Evaluation).

Spoiler sensor data is not used with flaps up.
Autopilot not engaged.

Autopilot would not command overbank and would still follow correct path command (if it was engaged).
(Supported by system evaluation)

Thus this condition could be ruled out

6.2.2.5 IRU Faults

All the following scenarios require:
1. Autopilot failed to “engaged state” but outputting disengaged status data to FDR
2. FCC must command airplane to bank angle above 30 degrees

No FCC internal faults can lead to A/P engagement or erroneous commands)

6.2.2.5.1 IRU Shutdown

Not supported by FDR Data, thus this condition could be ruled out

6.2.2.5.2 Erroneous L IRU Output of Roll Rate

FDR records roll data used by FD - not erroneous

Correct roll data requires correct roll rate data (Supported by System Evaluation + FDR data), thus this condition could be ruled out

6.2.2.5.3 R IRU of NCD for Roll Rate

(This scenario requires-

1 Autopilot failed to “engaged” state but outputting disengaged status data to FDR.

2 Internal faults within IRU that allow incorrect roll data to be transmitted to FCC, EADI

(Supported by System evaluation + FDR)

Thus this condition could be ruled out

6.2.2.5.4 Erroneous R IRU Output of Straight and level flight during bank

Would result in:

1. Autopilot actuator hardover.
2. Captain FD would provide correct steering cues
3. F/OEADI would display straight and level flight ("Overbank annunciations must therefore be based on some other source")
4. F/OFD would display erroneous steering cues
5. Roll comparator annunciated

Thus this condition could be ruled out

6.3 Lateral System Fault

(See Appendix 2-1 analysis for lateral control system)

6.3.1 Jam

6.3.1.1 Between Wheel and PCU

Both ailerons showed movements through the whole flight. (Supported by performance; FDR Match)
This condition could be ruled out

6.3.1.2 Between PCU and Aileron

Both ailerons showed movements through the whole flight. (Supported by performance; FDR Match)
This condition could be ruled out

6.3.2 Aileron PCU Hardover

Based on Performance; FDR Match + M-Cab test results, this condition could be ruled out

6.3.3 Cable Break

6.3.3.1 Between Wheel and PCU

Aileron movement in both directions noted on FDR

Based on Performance; FDR Match, this condition could be ruled out

6.3.3.2 Between PCU and Aileron

Aileron movement in both directions noted on FDR

Based on Performance; FDR Match, this condition could be ruled out

6.3.4 Trim/Feel Unit Fault

6.3.4 .1 Aileron Trim Runaway to Approx. 25 deg.

6.3.4 .2 Aileron Trim Runaway to 60 deg.

(See Appendix 2-1 lateral control analysis, Table 2 Hypothetical double failures scenarios (Ailerons/ Spoilers Systems), Scenario 2)

Assumptions:

- One trim switch stuck at closed position (could be a latent failure).
- Second trim switch might have stuck at closed position with trim input from the flying crew, leading to trim motor hardover position driving the ailerons to 15 degrees (maximum trim authority) towards right turn.
- This failure is assumed to occur after autopilot disconnect.

- Fault combined with pilot interference

The consequences of the hypothetical failure:

- The aileron trim actuator will reach its hardover position driving the ailerons to 15 degrees (maximum trim authority) at no load on the aileron control wheels.
- Both aileron wheels will be driven away from the neutral position. The ailerons and flight spoilers will always follow the aileron wheels. The new position for the wheel will be about 65 degrees at no load on the aileron control wheels. The force-wheels relation will change (refer to Figure 2.5.13.6 Ailerons and spoilers behavior with aileron trim actuator at its hardover position)
- Whenever the aileron wheels are released, the wheels will move to the hardover position (65 degree). The ailerons wheels will always follow each others simultaneously.
- No cockpit visual or audio warning
- The Captain and F/O will be able to resist the trim action and control the ailerons and spoilers but with additional force (Refer to Fig Figure 2.5.13.6)
- Whenever the Captain and F/O release the ailerons control wheels, the ailerons will tend to move towards right turn unless one of the flying crew exerts forces on the aileron control wheels to restore the airplane attitude

This condition could not be ruled out based on the following:

- With reference to the FDR data and after autopilot disconnect, the FDR shows tendency for the ailerons to move towards right turn direction. Movement of the aileron surfaces as shown in the FDR towards the neutral position could be explained by Captain attempts to control the airplane attitude with the existence of the failure.
- The movements of the ailerons throughout the last recovery phase highly support this scenario. The FDR data shows that even with the captain attempt to recover the airplane at the last stages, the ailerons always had the trend to move towards the opposite direction of correction which is highly consistent with the fault existence when the captain effort to restore the airplane is reduced. Forces are

higher than normal to overcome the centering springs.

- Based on evaluation in M-Cab, this event fits the data. However, trim fault must have occurred after autopilot engagement (zero force, zero aileron engagement indicates zero trim at that point).
- This hypothetical condition shows close consistency with the event. This condition is also consistent with the possibility of recovering the airplane when appropriate quantity of input is applied timely on the airplane (M- Cab tests).
- Consistent with Crew Behavior study

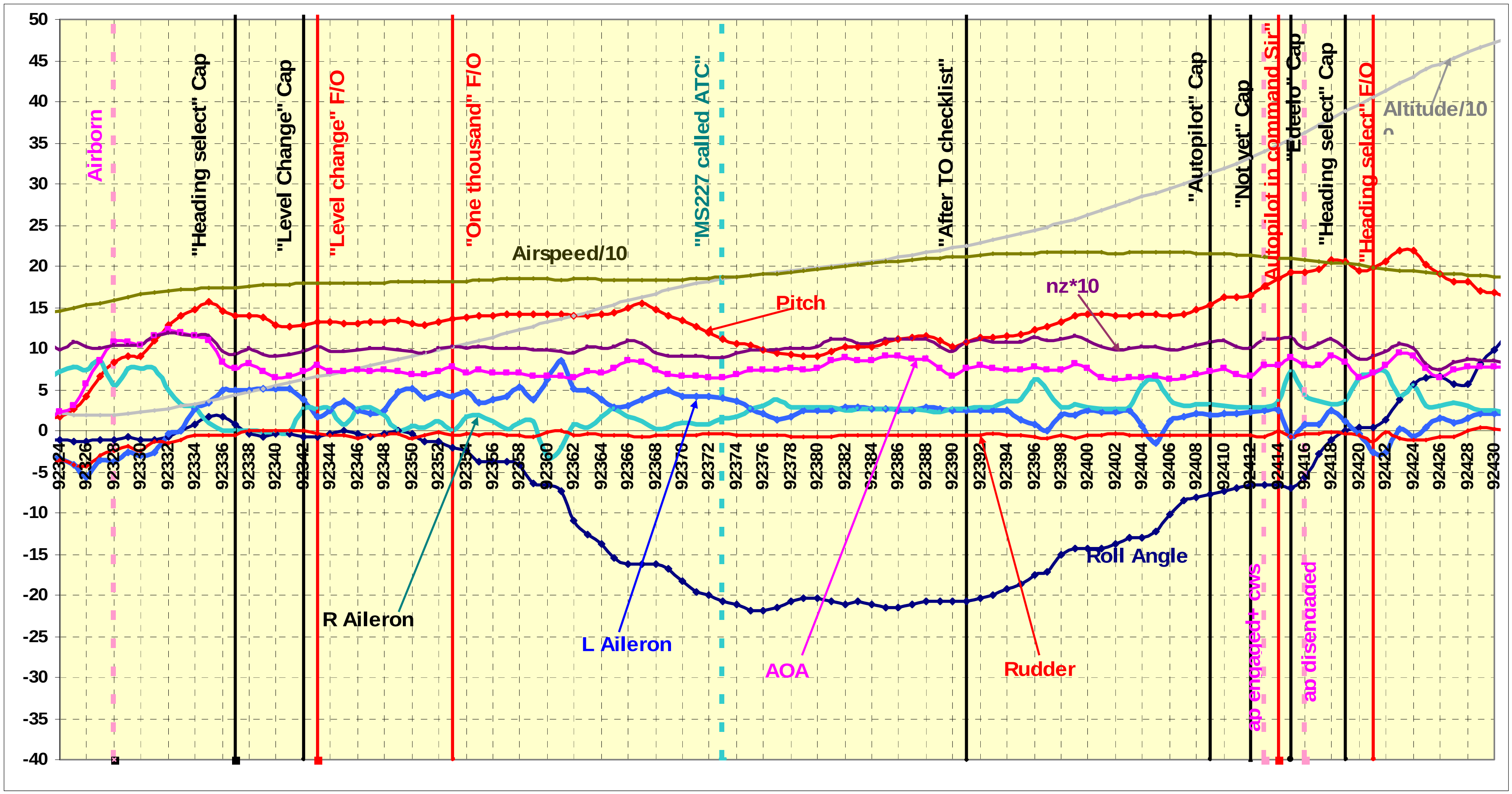


Figure 2.5.13.1b Right roll continues to overbank with ailerons activities

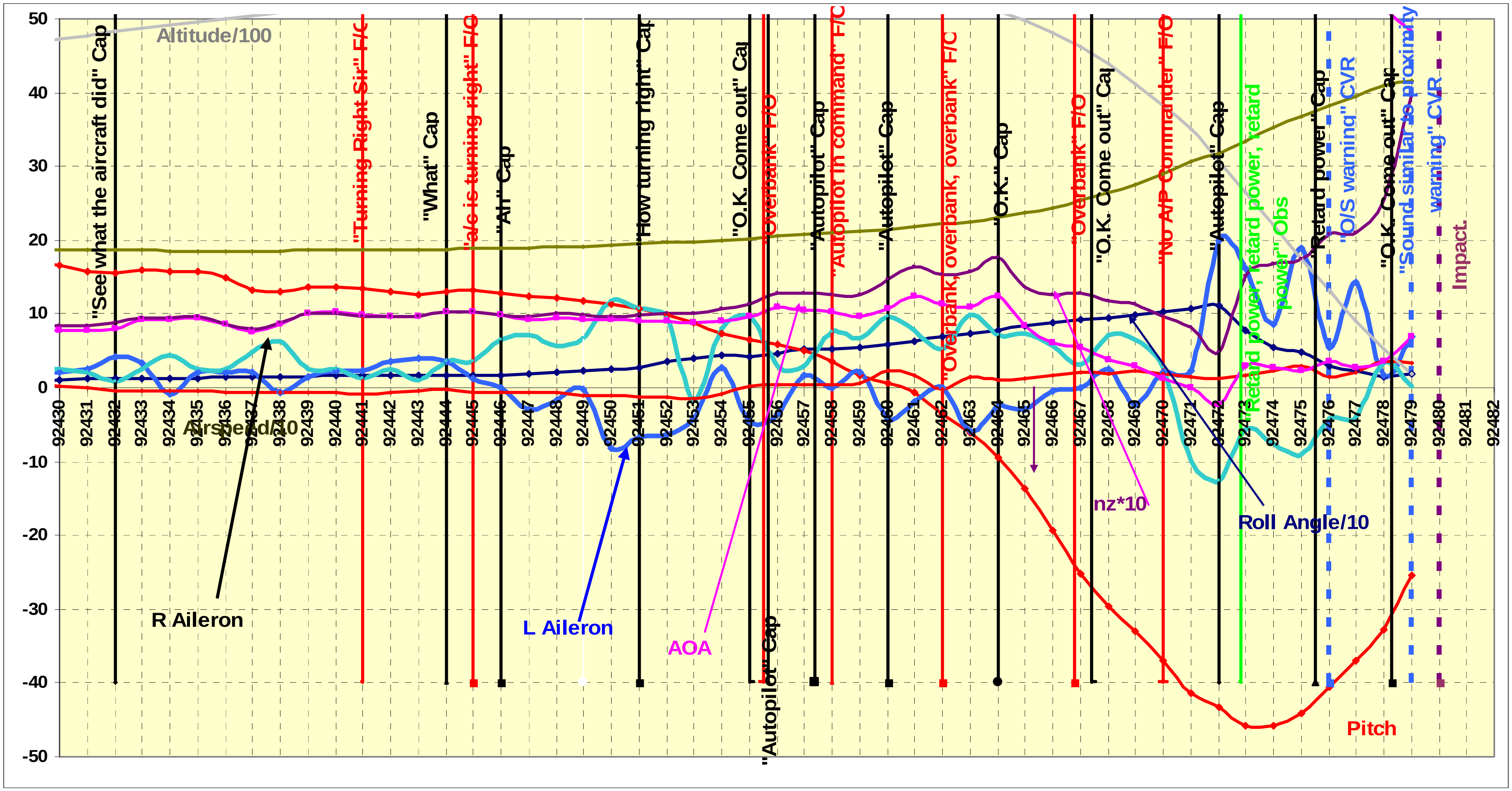


Figure 2.5.13.1c Right roll continues to overbank with ailerons activities

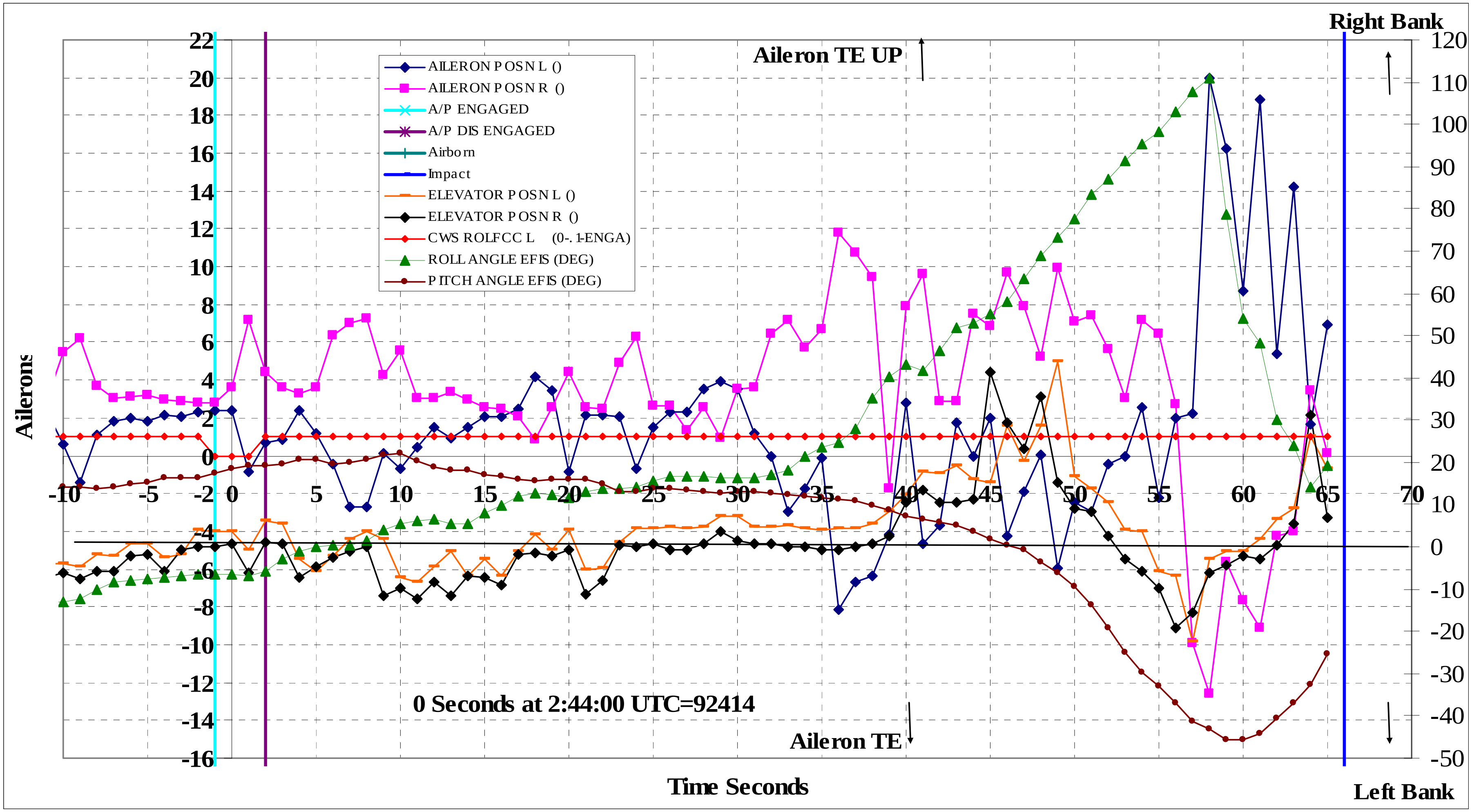


Figure 2.5.13.1d Right roll continues to overbank with ailerons activities

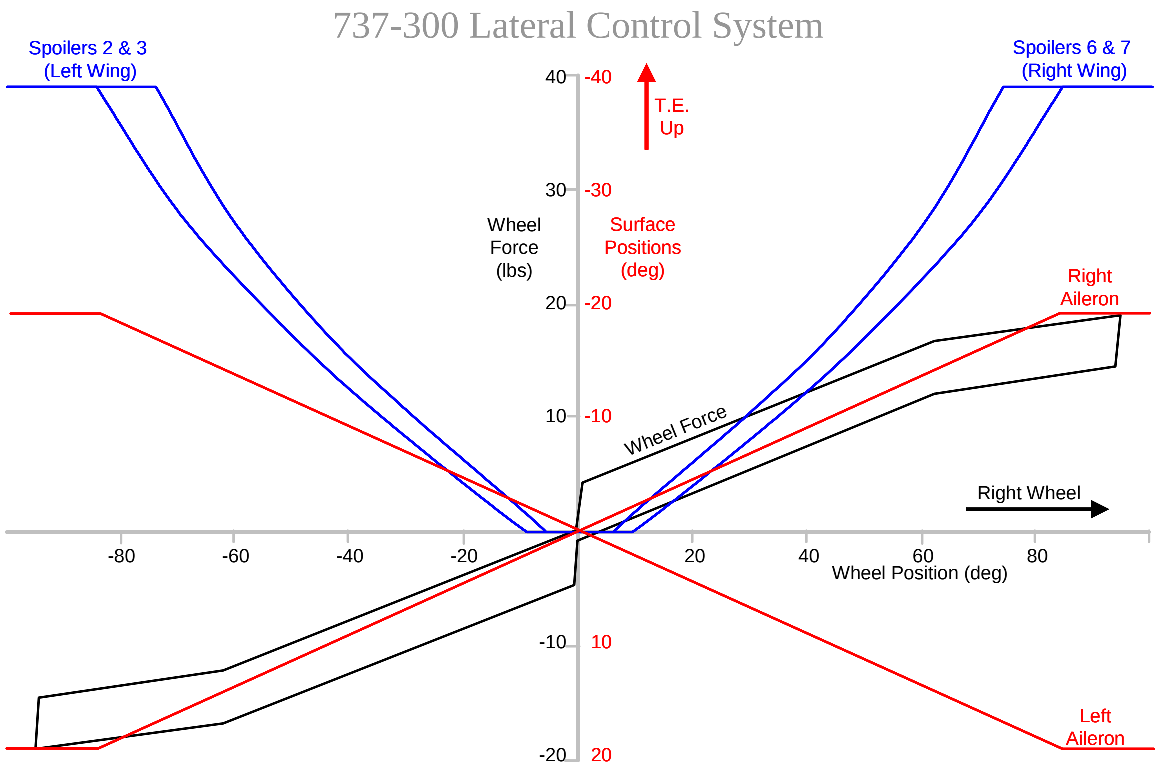


Figure 2.5.13.6 Ailerons and spoilers behavior with zero ailerons trim actuator

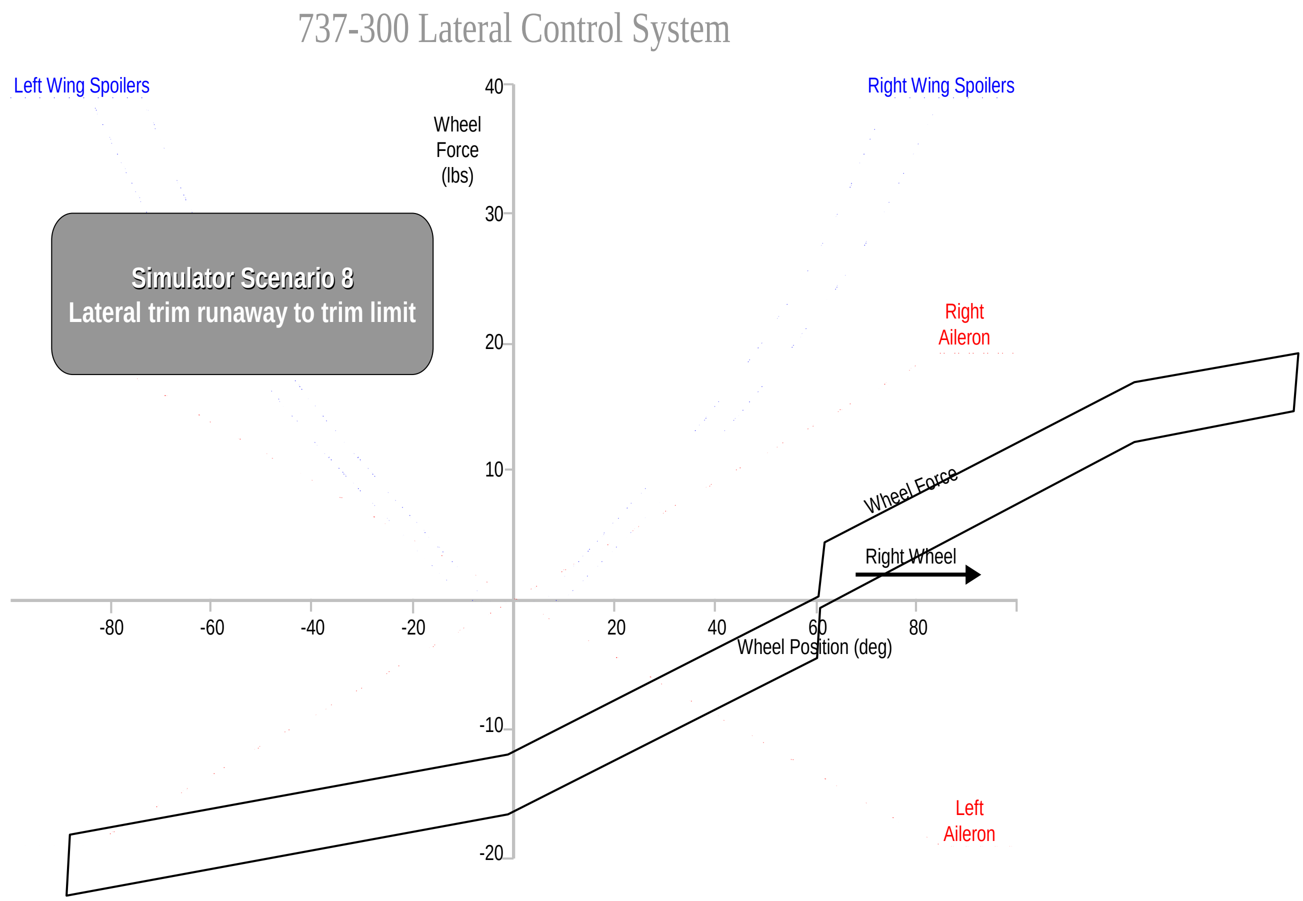


Figure 2.5.13.7 Ailerons and spoilers behavior with aileron trim actuator at its hardover position

6.3.5 Spoiler Fault

6.3.5.1 Spoiler Hardover

Based on the M- Cab results (Simulator match to FDR, Faults Simulations, results of spoilers' hardover conditions are shown hereafter), this condition shows inconsistency with the accident scenario. Therefore, this fault could be ruled out.

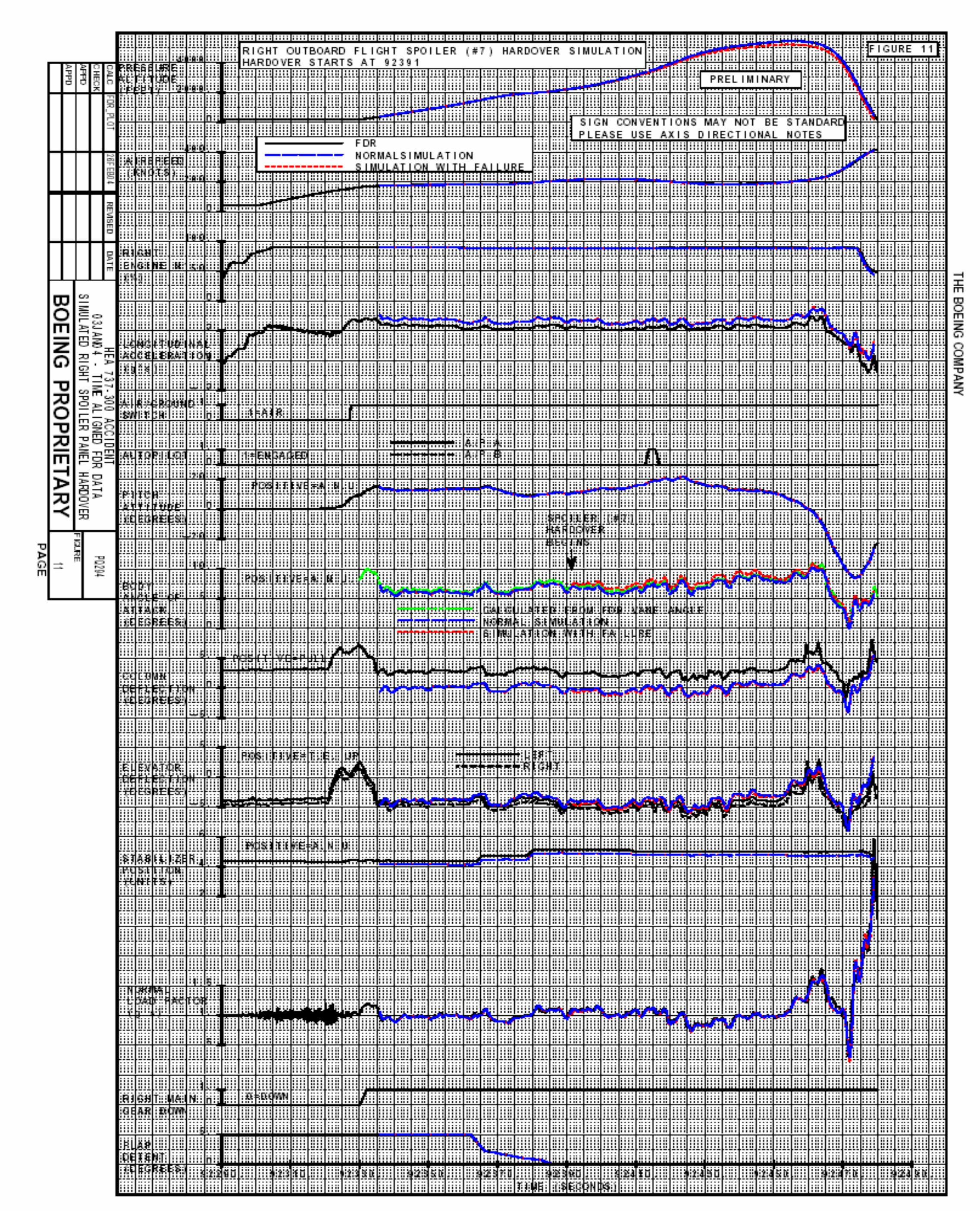


Figure 2.5.13.8a Right outboard flight spoilers (#7) Hardover simulation (hardover starts at 92391) (longitudinal)

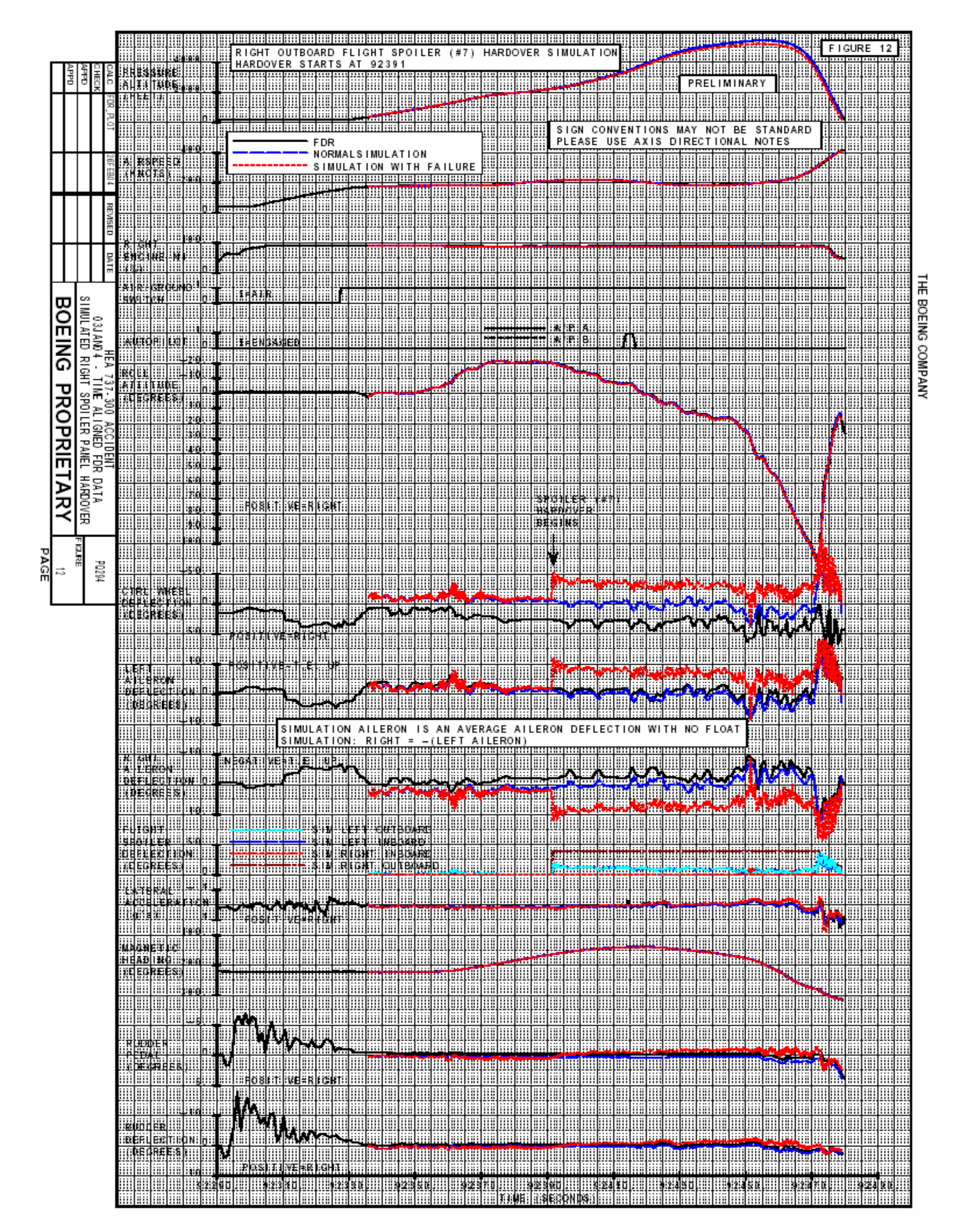


Figure 2.5.13.8b Right outboard flight spoilers (#7) Hardover simulation (hardover starts at 92391) (lateral)

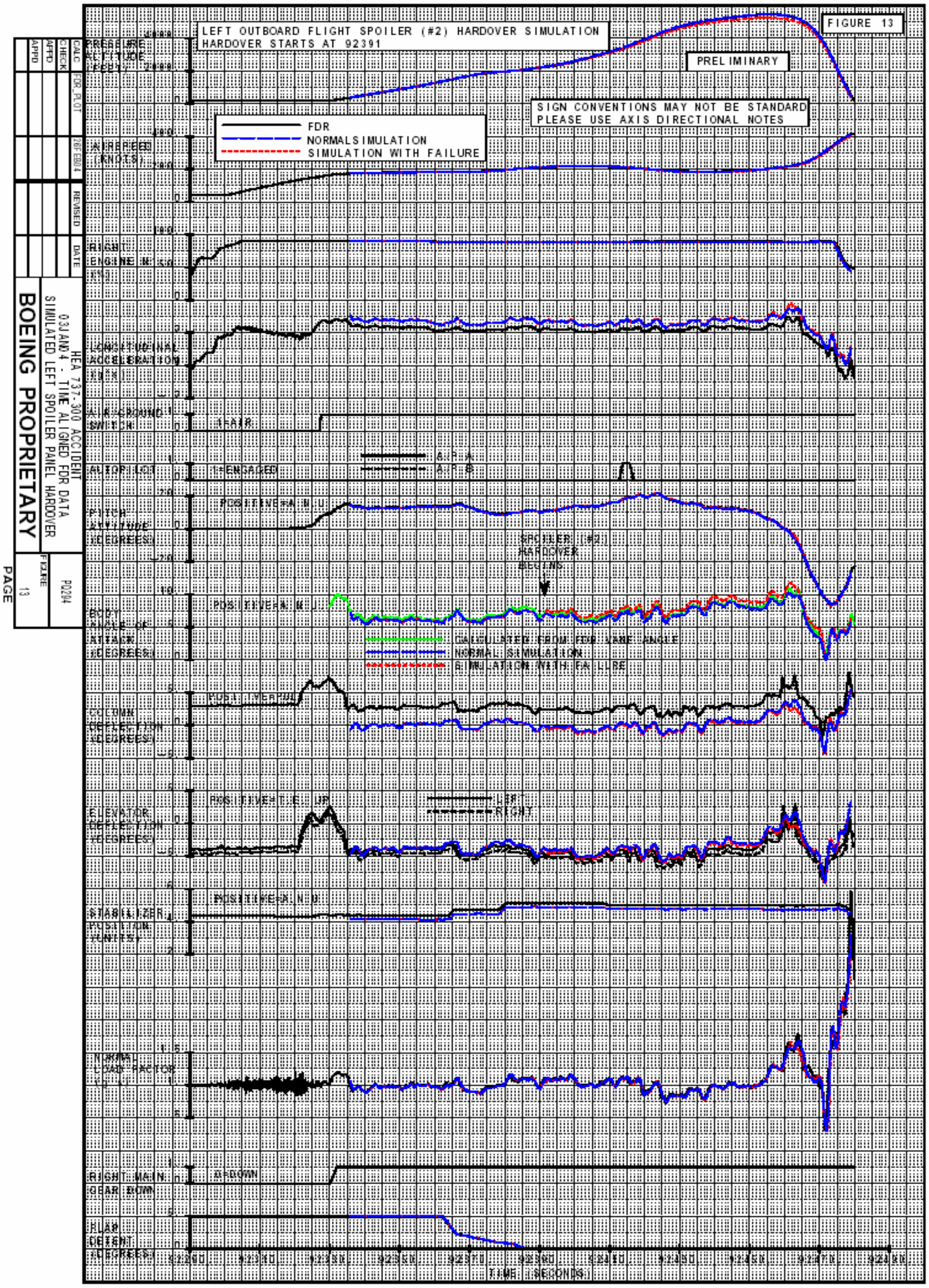


Figure 2.5.13.9a Left outboard flight spoilers (#2) Hardover simulation (hardover starts at 92391) (Longitudinal)

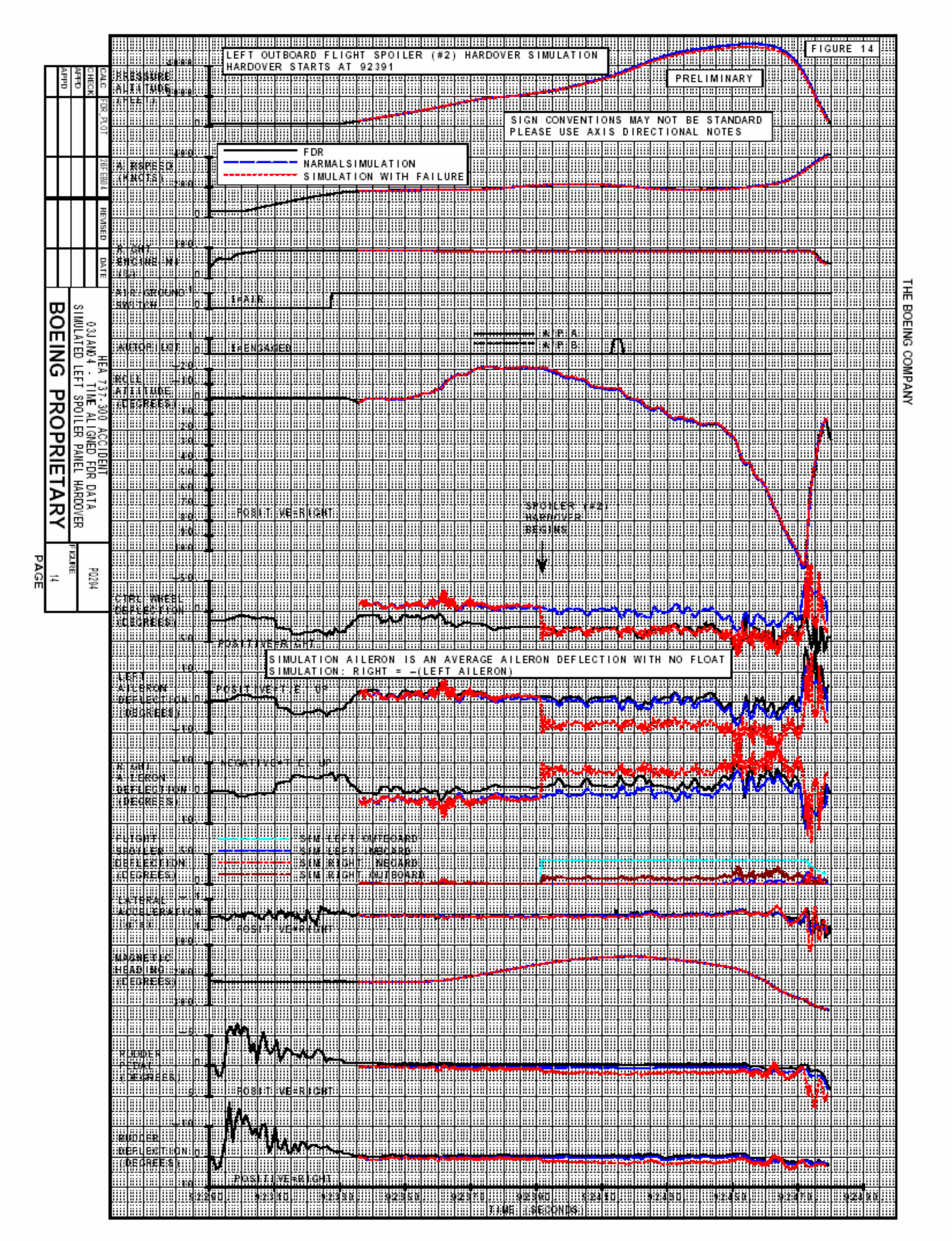


Figure 2.5.13.9b Left outboard flight spoilers (#2) Hardover simulation (hardover starts at 92391) (Lateral)

6.3.5.2 Spoiler Float

Based on the M- Cab results (Simulator match to FDR, Faults Simulations, results of spoilers’ float conditions are shown hereafter), this condition shows inconsistency with the accident scenario. Therefore, this fault could be ruled out.

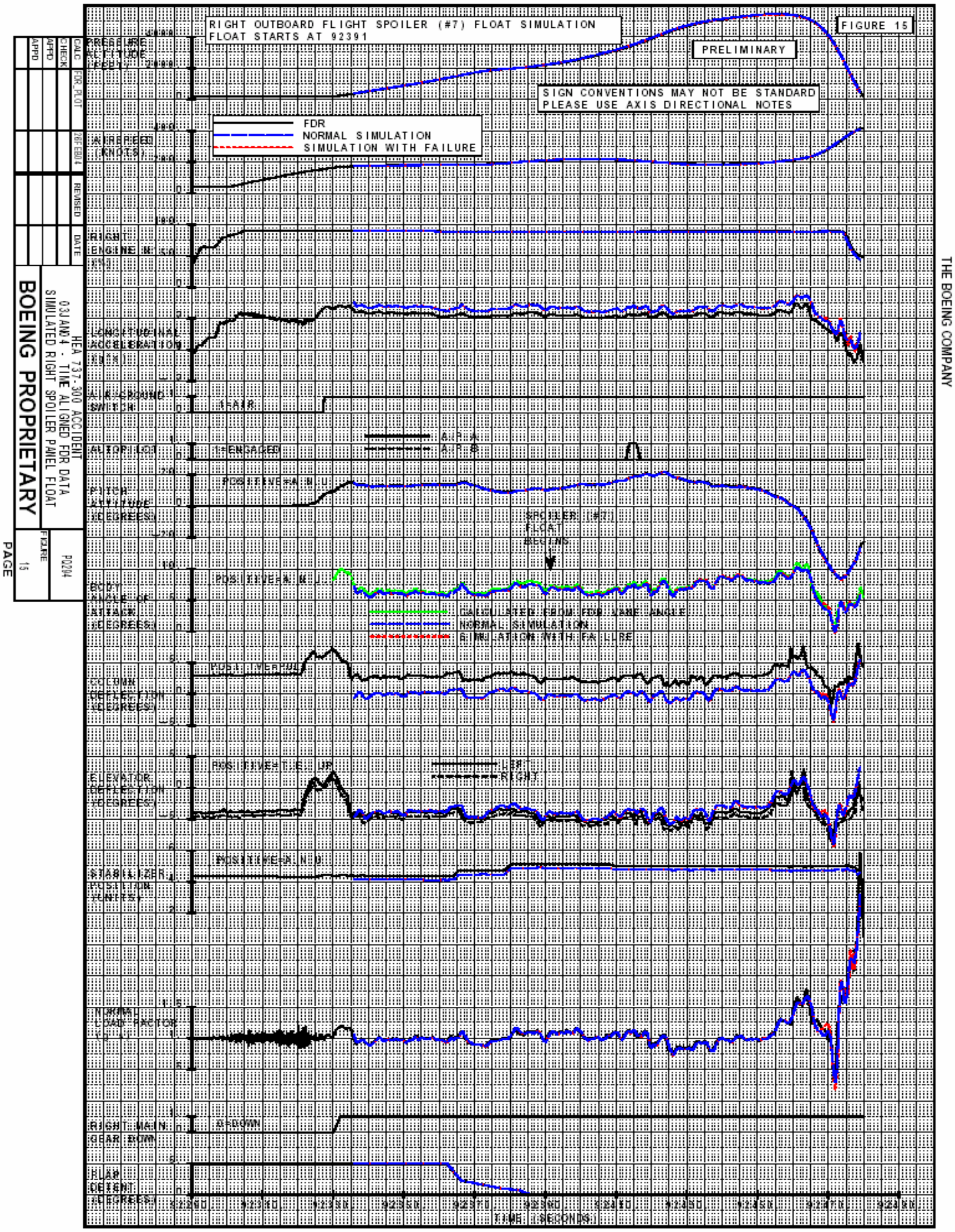


Figure 2.5.13.10a Right outboard flight spoilers (#7) Float simulation (floats starts at 92391) (Longitudinal)

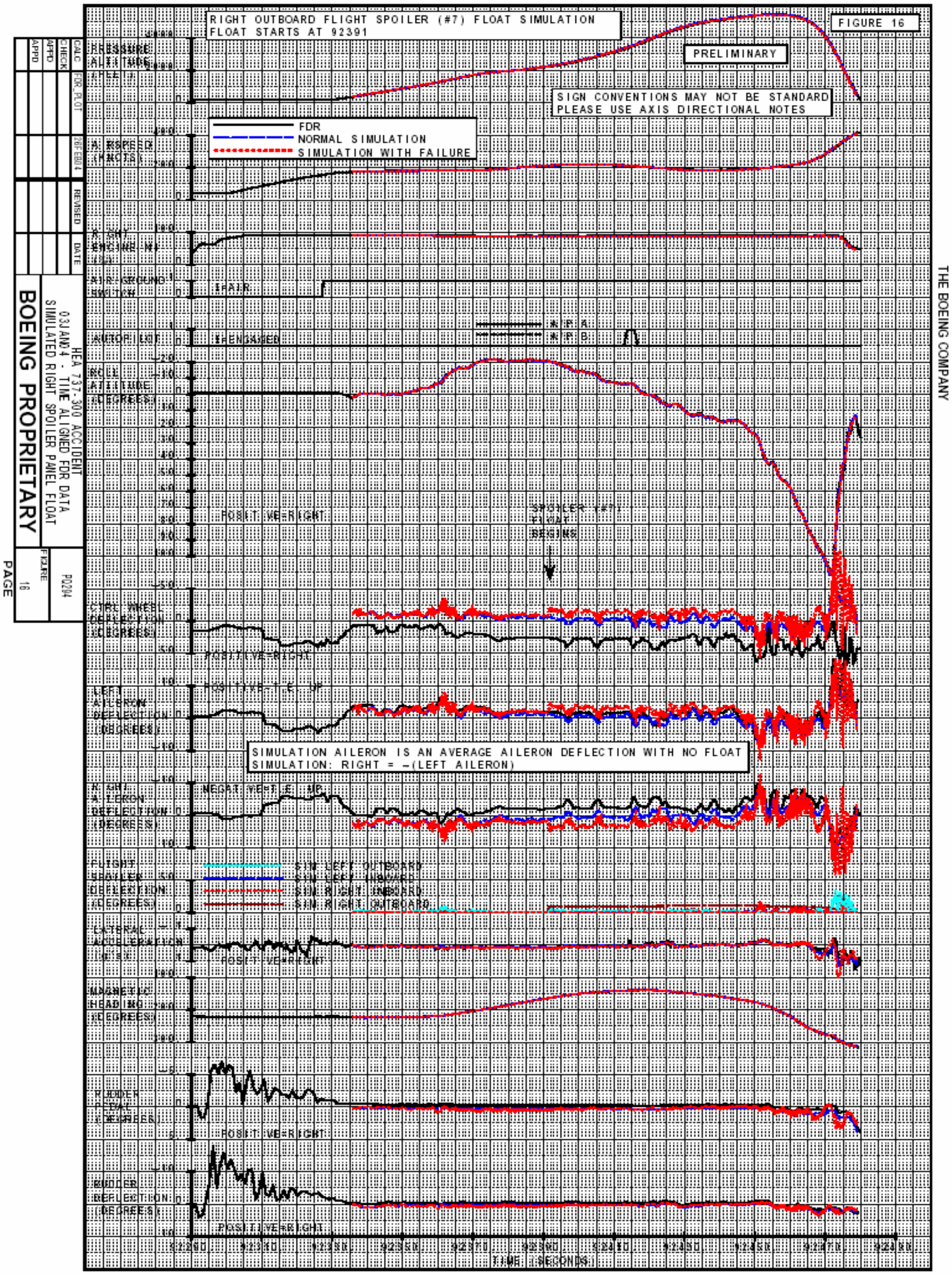


Figure 2.5.13.10b Right outboard flight spoilers (#7) Float simulation (floats starts at 92391) (Lateral)

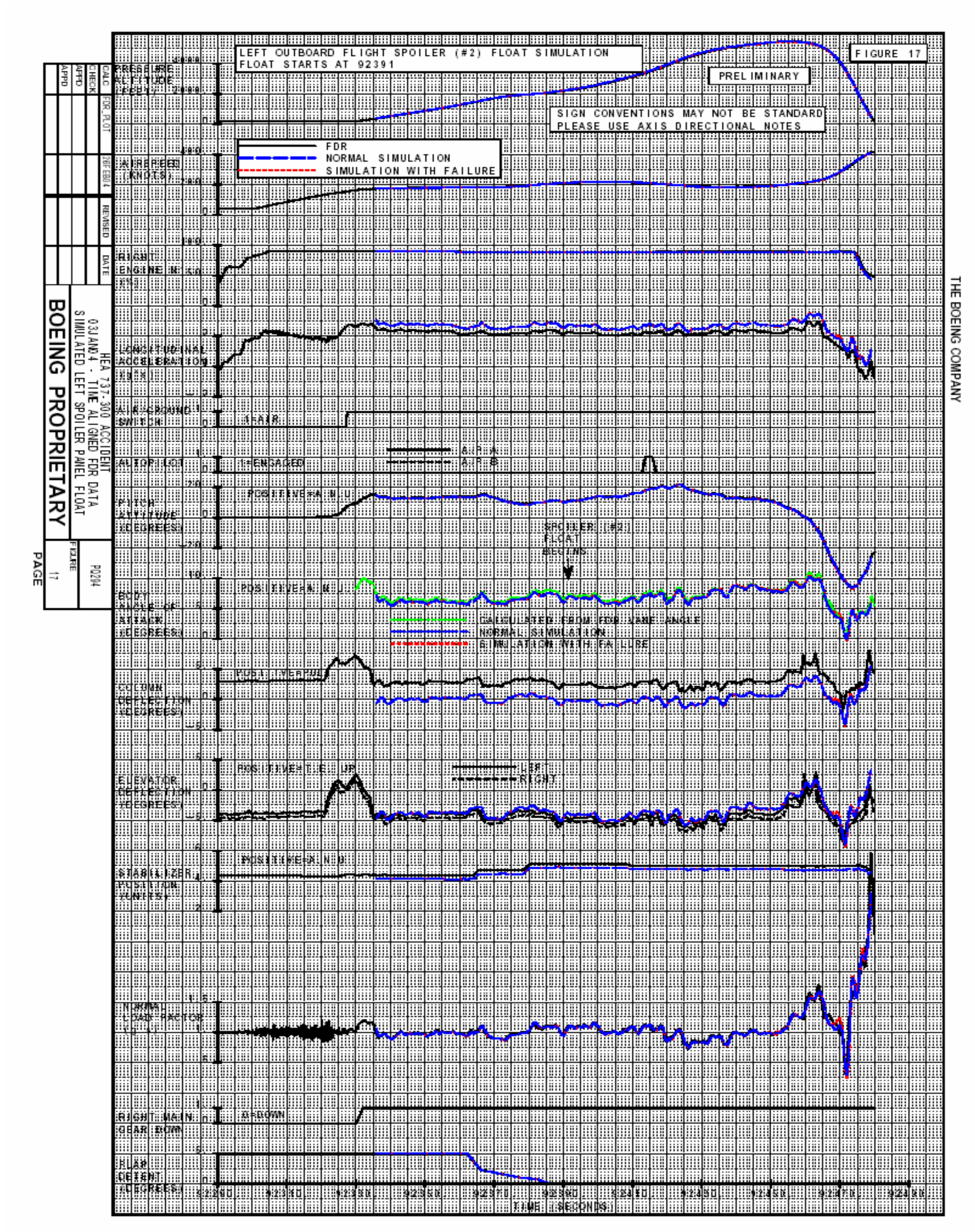


Figure 2.5.13.11a Left outboard flight spoilers (#2) Float simulation (floats starts at 92391) (Longitudinal)

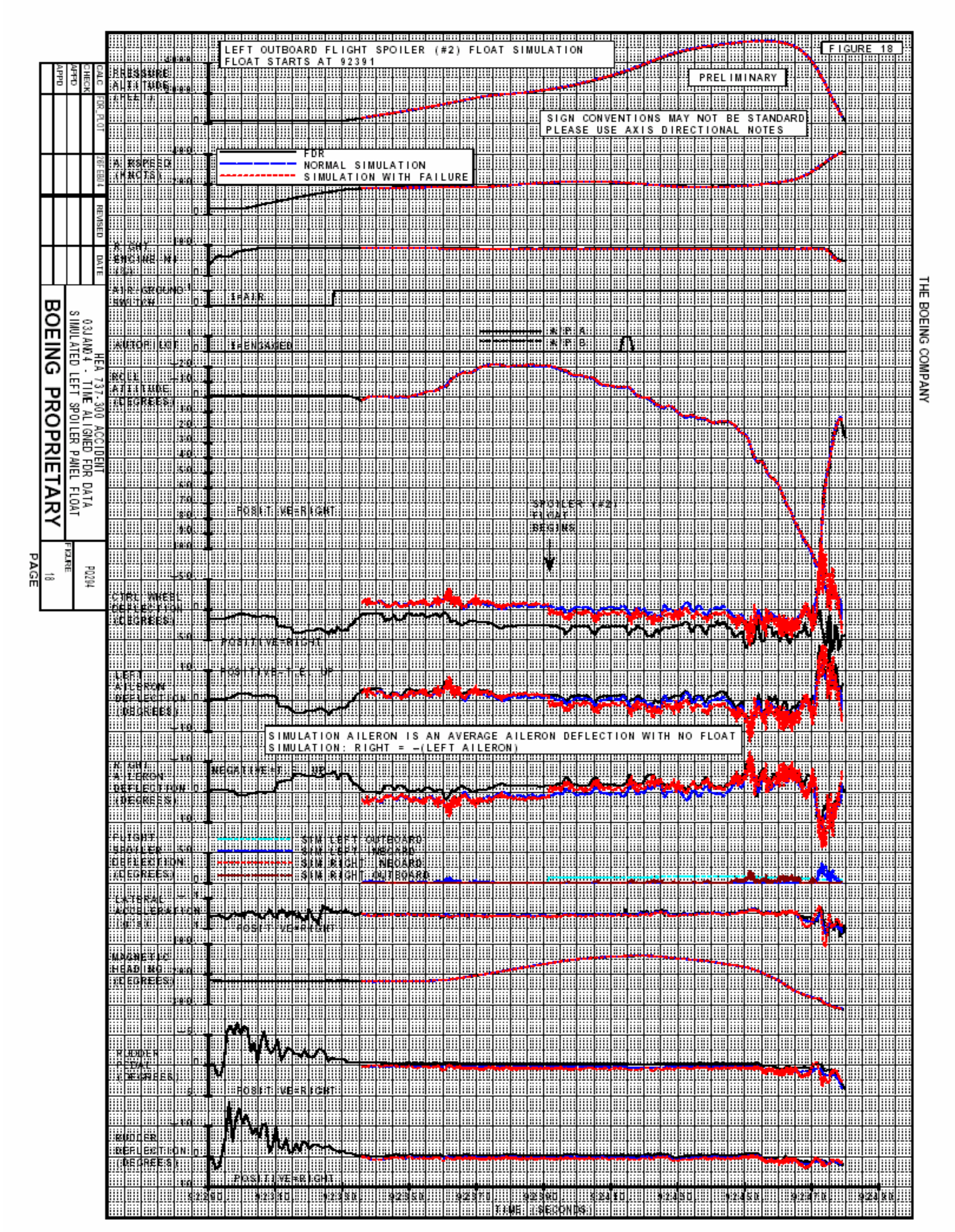


Figure 2.5.13.11b Left outboard flight spoilers (#2) Float simulation (floats starts at 92391) (Lateral)

6.3.5.3 Spoiler Mid-Position Jam

6.3.5.3.1 Scenario 10 - Spoiler wing cable jam
(Spoiler wing cable jam) offset of the neutral position at time 92450 (maximum wheel deflection).and clears at 92472

(Refer to appendix 2-1 lateral control analysis, Table 1 Hypothetical failures scenarios (Ailerons/ Spoilers Systems), Scenario 10)

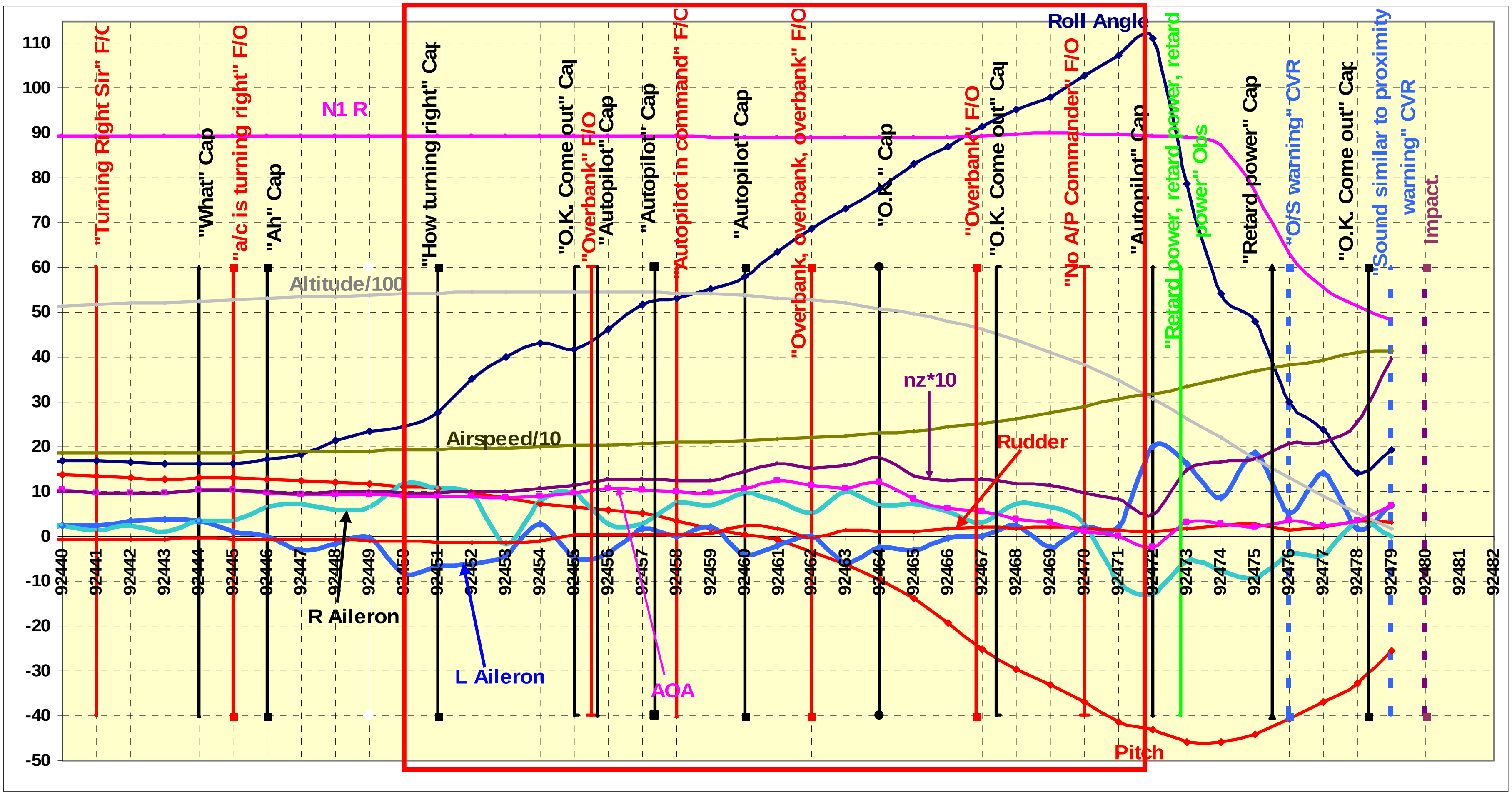


Figure 2.5.13.12 Right roll continues to overbank with ailerons activities (condition F3)

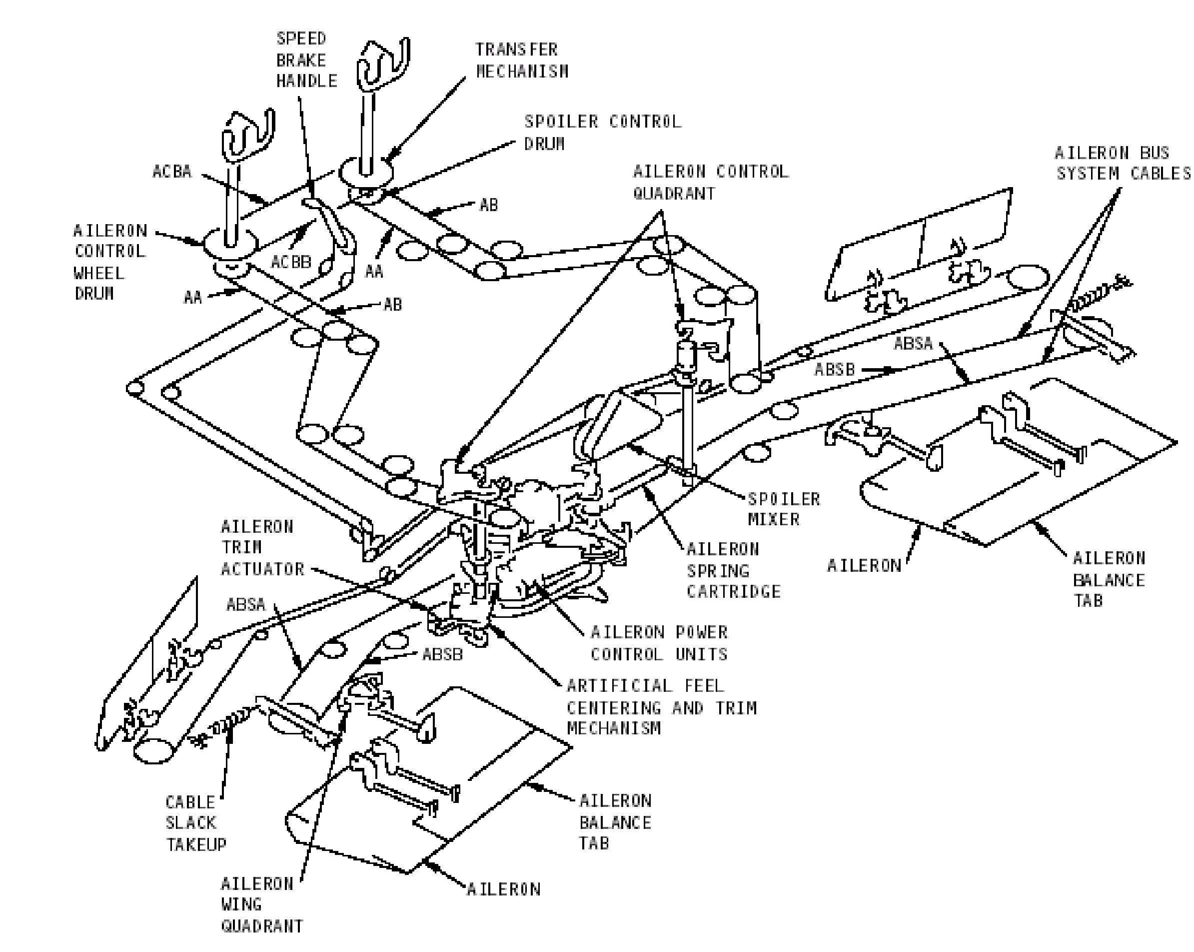


Figure 2.5.13.13 Lateral Control System

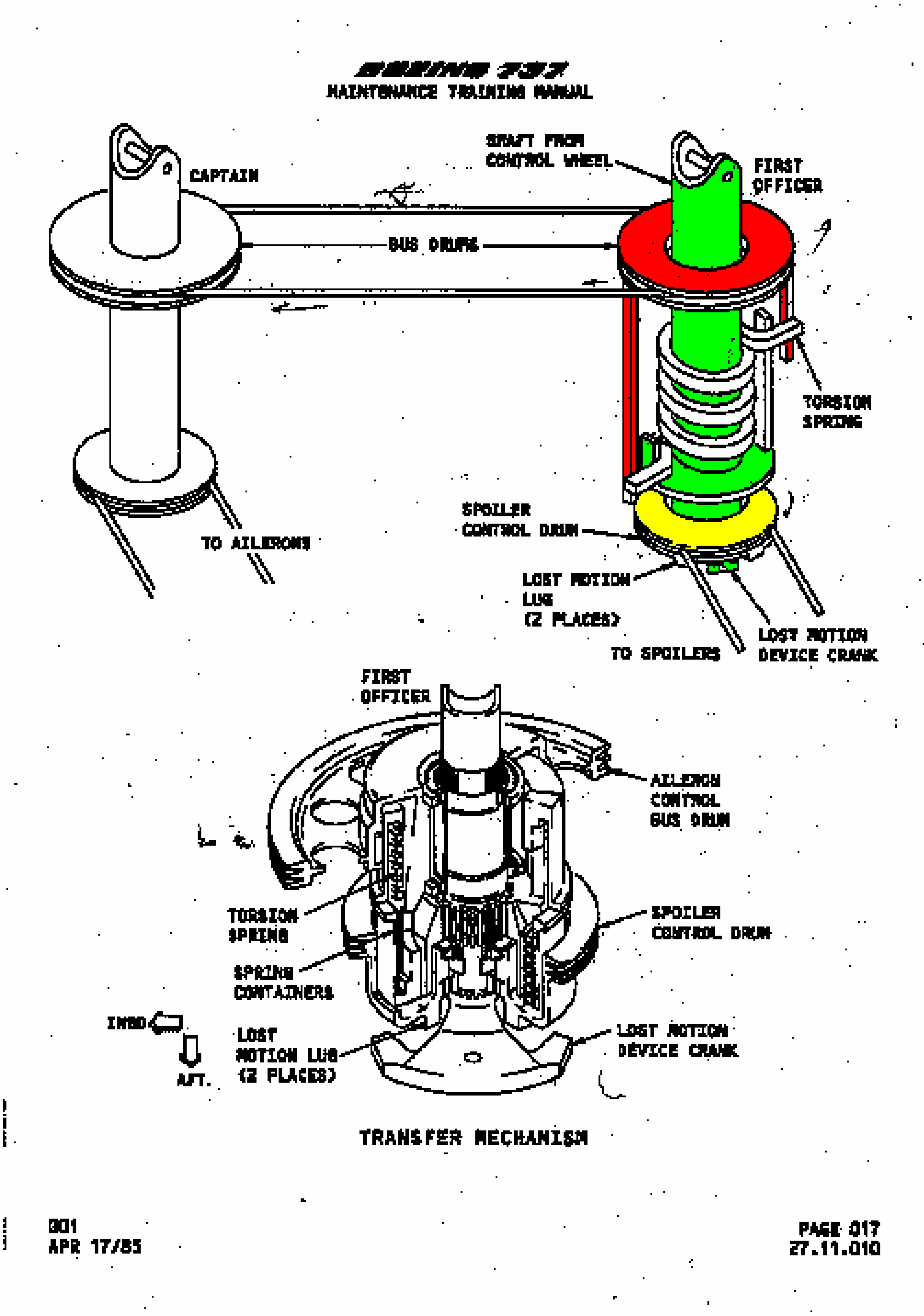


Figure 2.5.13.14 Transfer Mechanism

Assumptions:

- The spoiler wing cable is assumed to jam offset of the neutral position at time 2:44:36 (92450 time frames in seconds). At this time the ailerons and based on the FDR data, the aileron wheels were at their maximum deflections
- The left aileron was at 8.1 degrees TED[2], the right aileron was at 11.8 degrees. The airplane pitch angle was 11.25 degrees. The roll angle was 24.6 degrees (right roll)
- This fault is assumed to be cleared at 2:44:58 (92472 time frames in seconds) (beginning of the recovery effort.

Consequences of the hypothetical failure:

- The spoiler control drum will jam the lost motion device crank offset of the neutral position.
- The ailerons control wheels will, when released (no load condition) move and remain at a position equal to the position at the moment of the jam (about 40 degrees right roll-FDR data) minus 12 degrees (transfer mechanism lost motion), resulting in about 28 degree wheel deflection in the right roll direction.
- "The flight spoilers will remain in the position corresponding to the position of the jammed spoilers wing cables, irrespective of any mechanical inputs from either control wheel (about 12 degrees- FDR data). The ailerons can still be controlled via the captain's wheel. However, movement of aileron wheel towards airplane left turn (to correct for the right bank tendency) will be opposed by the override mechanism spring, consequently the forces required to move the ailerons in this direction will be significantly higher than the normal forces at no fault (about 50 lbs additional force)
- The F/O will not be able to control the ailerons in the direction of airplane left turn, with limited ability to control it in the direction of airplane right turn.
- This fault will not be associated with any visual or audio warning in the cockpit

•

[2] TED= Trailing Edge Down, TEU=Trailing Edge Up

Results of the M-Cab test[3]:

- During the meetings in Cairo on August 05, the MCA asked Boeing to redo simulations of scenarios 10 (spoiler cable jam) with the hypothetical fault inserted at the point of maximum wheel displacement and removed at the beginning of the recovery effort.

- Figure 2.5.13.15a (longitudinal parameters) and Figure 2.5.13.15b (lateral parameters) show the effect of the hypothetical spoiler cable jam fault.

[3] This test was done on Boeing M-Cab, Seattle, Washington

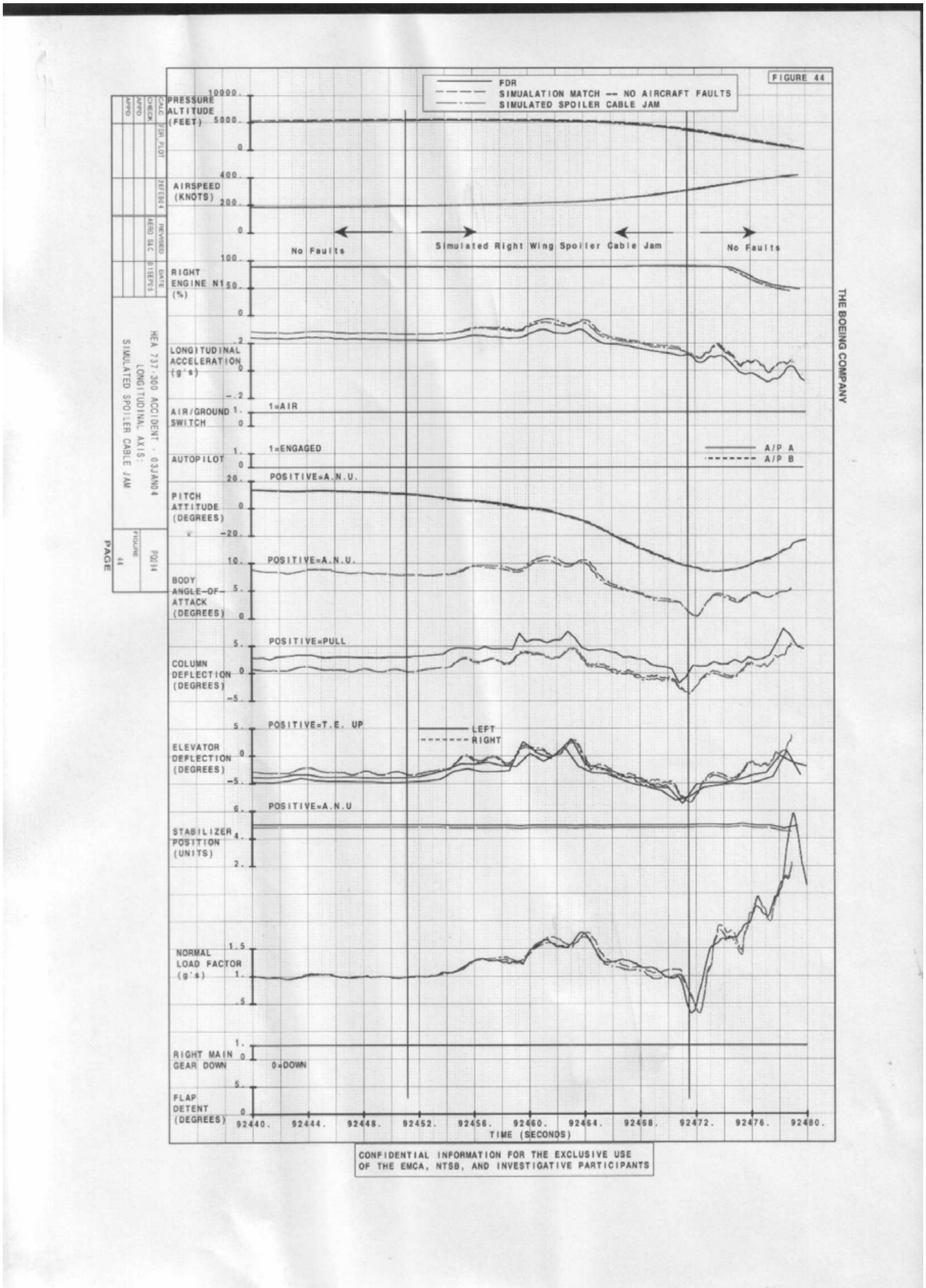


Figure 2.5.13.15a (longitudinal parameters)

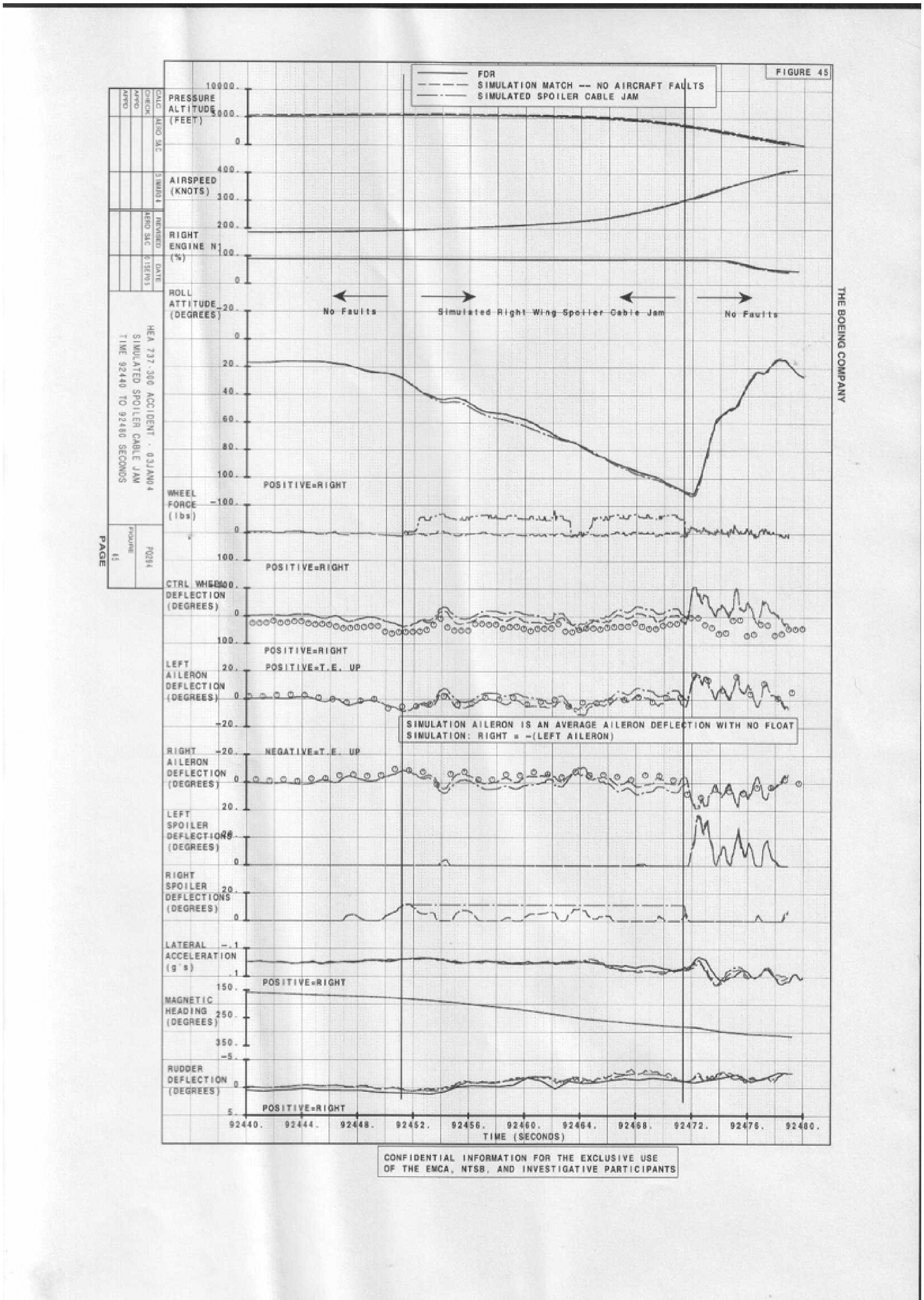


Figure 2.5.13.15b (lateral parameters)

- The simulations take into account the effects of blowdown on the ailerons. However, the blowdown effects on the spoilers are not included because of the way in which these hypothetical faults were simulated. The effects of spoiler blowdown are not expected to be large as spoiler deflections remain below 20 degrees and airspeed during the time of the fault remains below 310 knots.

- The longitudinal plot (Figures Figure 2.5.13.15a) included the following parameters:
    - Press Altitude (Feet)
    - Airspeed (Knots)
    - Right engine N1 (%)
    - Longitudinal acceleration (g's)
    - Air/ Ground switch
    - Autopilot status
    - Pitch attitude (Degrees)
    - Body angle of attack (Degrees)
    - Column deflection (Degrees)
    - Elevator deflection (Degrees)
    - Stabilizer position (Units)
    - Normal load factor (g's)
    - Right main gear down
    - Flap detent (Degrees)

- The lateral plot (Figures Figure 2.5.13.15b) included the following parameters:
    - Press Altitude
    - Airspeed (Knots)
    - Right engine N1 (%)
    - Roll attitude (Degrees)
    - Wheel force (lbs)
    - Control wheel deflection (Degrees)
    - Left aileron deflection (Degrees)
    - Right aileron deflection (Degrees)
    - Left spoiler deflection (Degrees)
    - Right spoiler deflection (Degrees)
    - Lateral acceleration (g's)
    - Magnetic heading (Degrees)
    - Rudder deflection (Degrees)
- All the parameters obtained from the M-Cab test with the fault inserted show very close consistency with the accident flight FDR data

.

- It is expected that wheel forces with higher magnitude can affect the speech pattern

It is noticed that there were no captain speeches when the ailerons were near to their neutral position. Most of the speeches were made at the timing where the ailerons were moving back to their position relevant to spoilers cables jammed condition

This condition could not be ruled out, based on the following:

- *A- The results obtained from the analytical studies and the M-Cab test show a close consistency with the available data.*
- *B- The airplane behavior is consistent with the consequences of the hypothetical fault:*
    - The ailerons movements towards airplane right roll are highly consistent with the expected position resulted from this hypothetical fault.
    - This fault always drive the airplane in the right roll direction
    - Movement of the aileron surfaces as shown in the FDR towards the neutral position are consistent with captain attempts to control the airplane attitude with the existence of the failure, the rate of airplane rolling to the right is always reduced with these attempts. The forces required to move the ailerons by the captain are considerably higher than the forces required in normal condition with no fault.
    - Whenever the captain control wheel is released, the ailerons move towards the offset position showing high consistency with the fault existence. The fault was continually driving the airplane towards more right roll
    - The movements of the ailerons throughout the last recovery phase highly support this scenario.
    - In the analysis in section 2.5.11 studying the chronological event where the airplane stopped the left turn and started a right turn at about 92420, the pilot input probability was not ruled out as one of the possible causes for this event. This input might be due to temporary loss of Situational Awareness. This explains how the airplane got to the point in the right roll at which the temporary jams supposedly occurred.
    - It is expected that wheel forces with higher magnitude can affect the speech pattern, however, it is noticed that there were no captain speeches when the ailerons were

near to their neutral position, most of the speeches were made at the timing where the ailerons were moving back to their position relevant to spoilers cables jammed condition. The timing and length of the Captain speeches through this event does not provide sufficient information to verify the effect of this force on the speech tone

- Crew behavior shows consistency

- 6.3.5.3.2 Scenario 10a - F/O wheel jam

(F/O wheel jam) offset of the neutral position at time 92450 (maximum wheel deflection).and clears at 92472

(Refer to appendix 2-1 lateral control analysis, Table 1 Hypothetical failures scenarios (Ailerons/ Spoilers Systems), Scenario 10a)

Assumptions:

- The F/O wheel is assumed to jam offset of the neutral position at time 2:44:36 (92450 time frames in seconds). At this time, and based on the FDR data, the aileron wheels were at their maximum deflections
- The left aileron was at 8.1 degrees TED, the right aileron was at 11.8 degrees. The airplane pitch angle was 11.25 degrees. The roll angle was 24.6 degrees (right roll)
- This fault is assumed to be cleared at 2:44:58 (92472 time frames in seconds) (beginning of the recovery effort.

Consequences of the the hypothetical failure:

- The F/O aileron control wheel will jam at a position offset of the neutral position relevant to the position of the jammed shaft.
- The ailerons control wheels will, <u>when released (no load condition)</u> remain at a position equal to the position at the moment of the jam (about 40 degrees right roll-FDR data). This corresponds to about 10 degrees of aileron deflections
- The flight spoilers will remain in the position corresponding to the position of the jammed spoilers wing cables (about 12 degrees- FDR data), however the captain will have a limited control on the spoilers within the transfer mechanism lost motion gap (± 12 degree) of aileron wheel deflection. (After 12 degrees of wheel rotation, the spoiler control drum lost motion lug will contact the lost motion device crank on the F/O control wheel shaft, preventing any further movement of the spoiler control drum. The spring cartridge will compensate for the continuing inputs from the ailerons bus drums).
- The ailerons can still be controlled via the captain's wheel. However, movement of aileron wheel in

either directions will be opposed by the override mechanism spring, consequently the forces required to move the ailerons in both directions will be significantly higher than the normal forces at no fault (about 50 lbs additional force)

- The F/O will not be able to control the ailerons nor the spoilers in either direction.
- This fault will not be associated with any visual or audio warning in the cockpit

Results of the M-Cab test[4]:

- Figure 2.5.13.15a (longitudinal parameters) and Figure 2.5.13.15b (lateral parameters) show the effect of the hypothetical spoiler cable jam fault.

[4] This test was done on Boeing M-Cab, Seattle, Washington

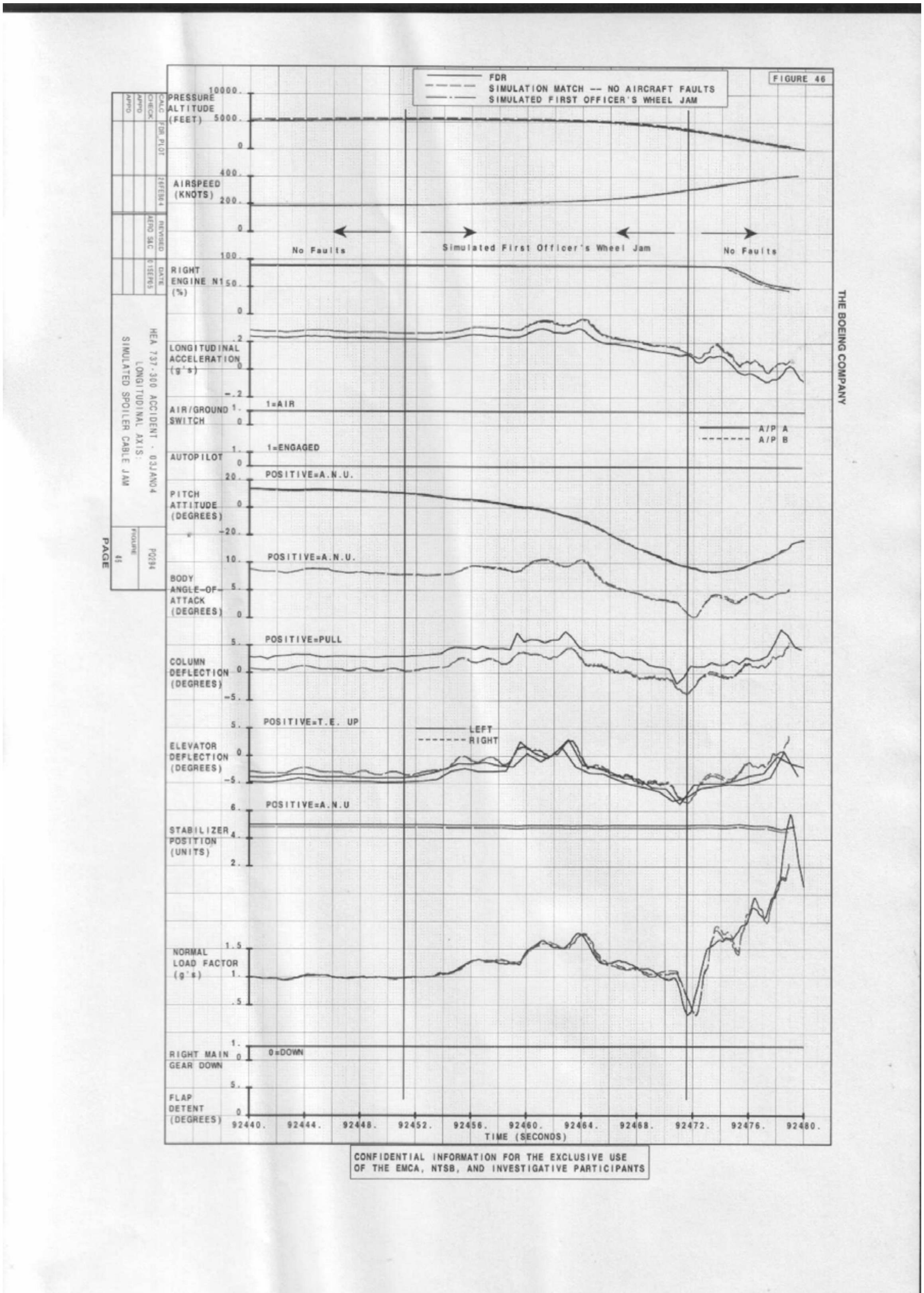


Figure 2.5.13.16a (longitudinal parameters)

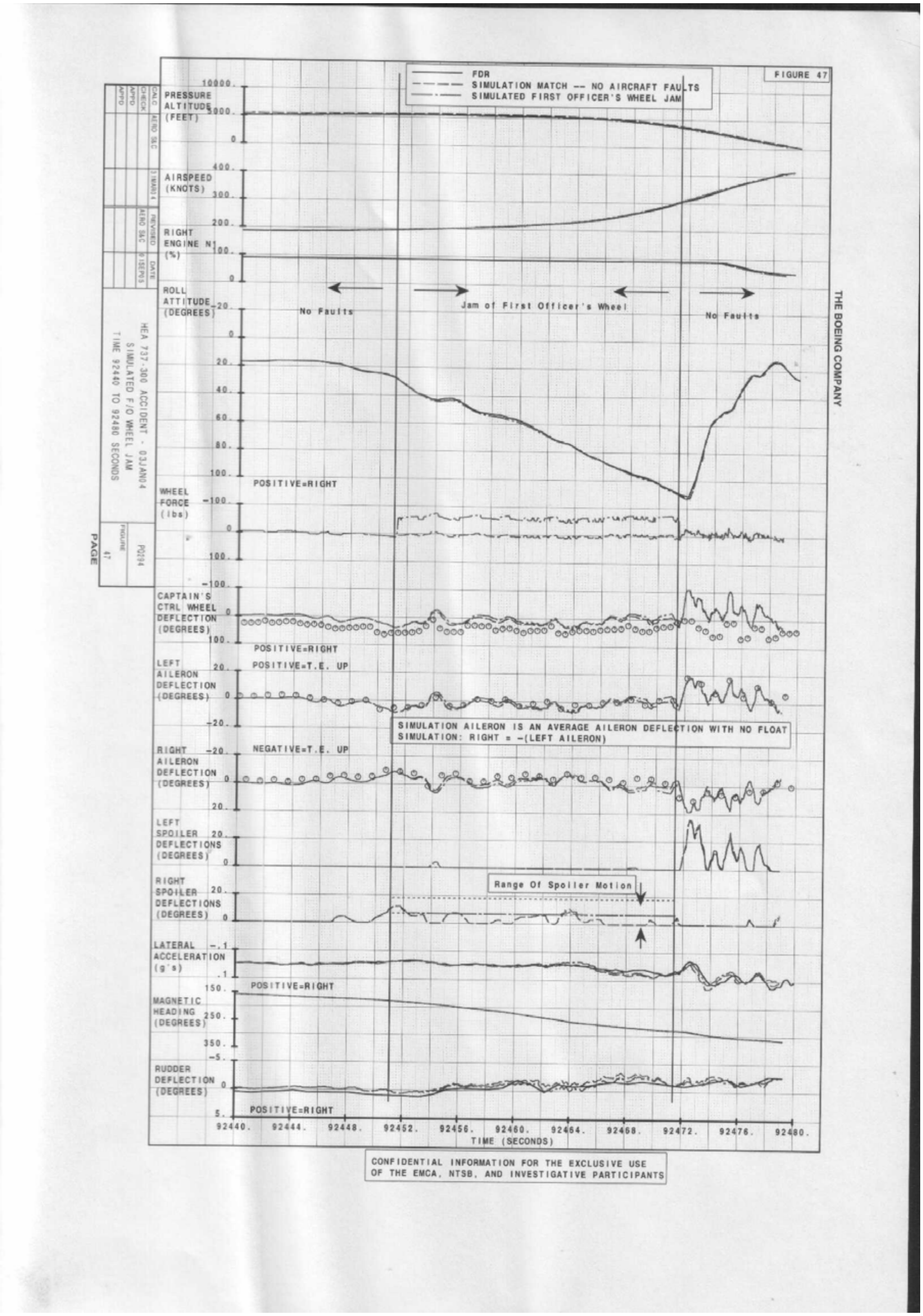


Figure 2.5.13.16b (lateral parameters

- In this scenario, the jam restricts further motion of the spoilers to the range of the lost motion device. Figure 2.5.13.15b shows that the right wing spoilers are limited to the range of 7 to about 17 degrees and the left wing spoilers are restricted to 0 degrees. The ailerons can still be controlled via the captain's wheel. There is an immediate significant increase in wheel force as the captain must overcome the spring force of the transfer mechanism.

- Both simulations take into account the effects of blowdown on the ailerons. However, the blowdown effects on the spoilers are not included because of the way in which these hypothetical faults were simulated. The effects of spoiler blowdown are not expected to be large as spoiler deflections remain below 20 degrees and airspeed during the time of the fault remains below 310 knots.

  Both figures include the wheel force required to overcome the transfer mechanism in the presence of the jam. It is significant to note that the force frequently exceeds 50 lbs.

- The longitudinal plot (Figure 2.5.13.16a) included the following parameters:
  - Press Altitude (Feet)
  - Airspeed (Knots)
  - Right engine N1 (%)
  - Longitudinal acceleration (g's)
  - Air/ Ground switch
  - Autopilot status
  - Pitch attitude (Degrees)
  - Body angle of attack (Degrees)
  - Column deflection (Degrees)
  - Elevator deflection (Degrees)
  - Stabilizer position (Units)
  - Normal load factor (g's)
  - Right main gear down
  - Flap detent (Degrees)

- The longitudinal plot (Figure 2.5.13.16b) included the following parameters:
  - Press Altitude
  - Airspeed (Knots)
  - Right engine N1 (%)
  - Roll attitude (Degrees)
  - Wheel force (lbs)
  - Control wheel deflection (Degrees)
  - Left aileron deflection (Degrees)

- Right aileron deflection (Degrees)
- Left spoiler deflection (Degrees)
- Right spoiler deflection (Degrees)
- Lateral acceleration (g's)
- Magnetic heading (Degrees)
- Rudder deflection (Degrees)

- All the parameters obtained from the M-Cab test with the fault inserted show very close consistency with the accident flight FDR data

- It is expected that wheel forces with higher magnitude can affect the speech pattern

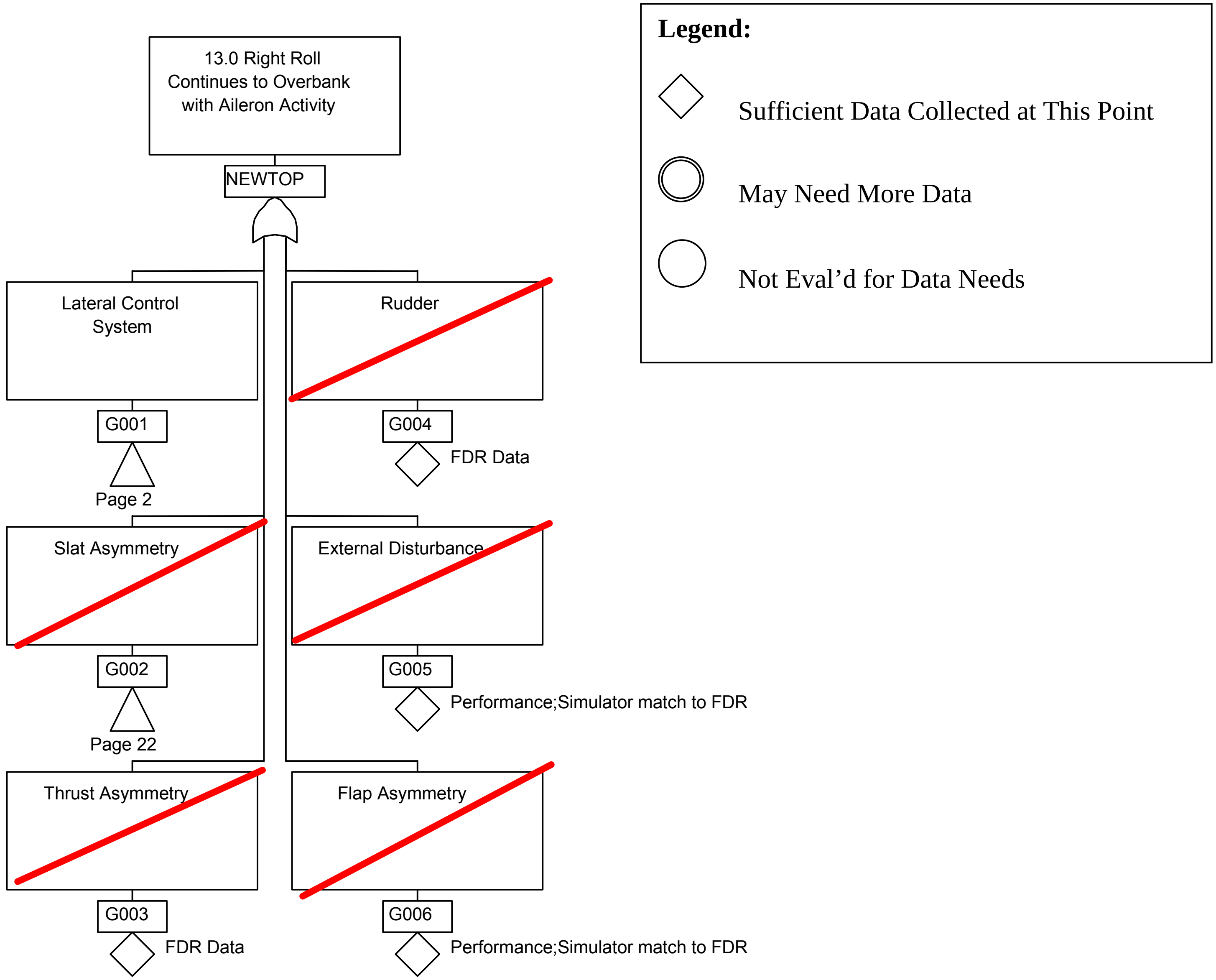
It is noticed that there were no captain speeches when the ailerons were near to their neutral position. Most of the speeches were made at the timing where the ailerons were moving back to their position relevant to spoilers cables jammed condition

This condition could not be ruled out, based on the following:

A. The results obtained from the analytical studies and the M-Cab test show a close consistency with the available data.
B. The airplane behavior is consistent with the consequences of the hypothetical fault:

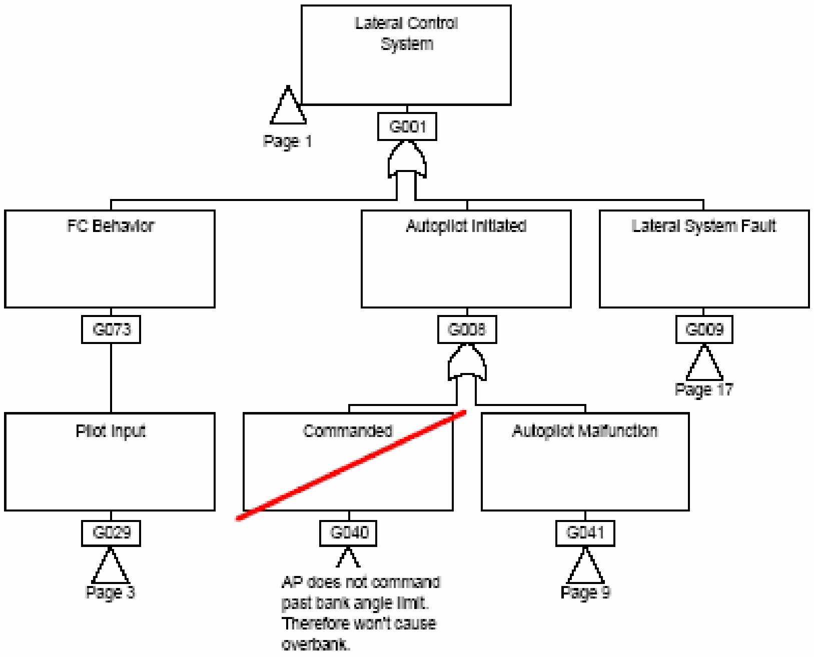
    - The ailerons movements towards airplane right roll are highly consistent with the expected position resulted from this hypothetical fault.
    - This fault always drive the airplane in the right roll direction
    - Movement of the aileron surfaces as shown in the FDR towards the neutral position are consistent with captain attempts to control the airplane attitude with the existence of the failure, the rate of airplane rolling to the right is always reduced with these attempts. The forces required to move the ailerons by the captain are considerably higher than the forces required in normal condition with no fault.
    - Whenever the captain control wheel is released, the ailerons move towards the offset position showing high consistency with the fault existence. The fault was continually driving the airplane towards more right roll
    - The movements of the ailerons throughout the last recovery phase highly support this scenario.

- In the analysis in section 2.5.11 studying the chronological event where the airplane stopped the left turn and started a right turn at about 92420, the pilot input probability was not ruled out as one of the possible causes for this event. This input might be due to momentarily loss of Situational Awareness. This explains how the airplane got to the point in the right roll at which the temporary jams supposedly occurred.
- It is expected that wheel forces with higher magnitude can affect the speech pattern, however, it is noticed that there were no captain speeches when the ailerons were near to their neutral position, most of the speeches were made at the timing where the ailerons were moving back to their position relevant to spoilers cables jammed condition. The timing and length of the Captain speeches through this event does not provide sufficient information to verify the effect of this force on the speech tone
- Crew behavior shows consistency



Cairo 4 Feb 05

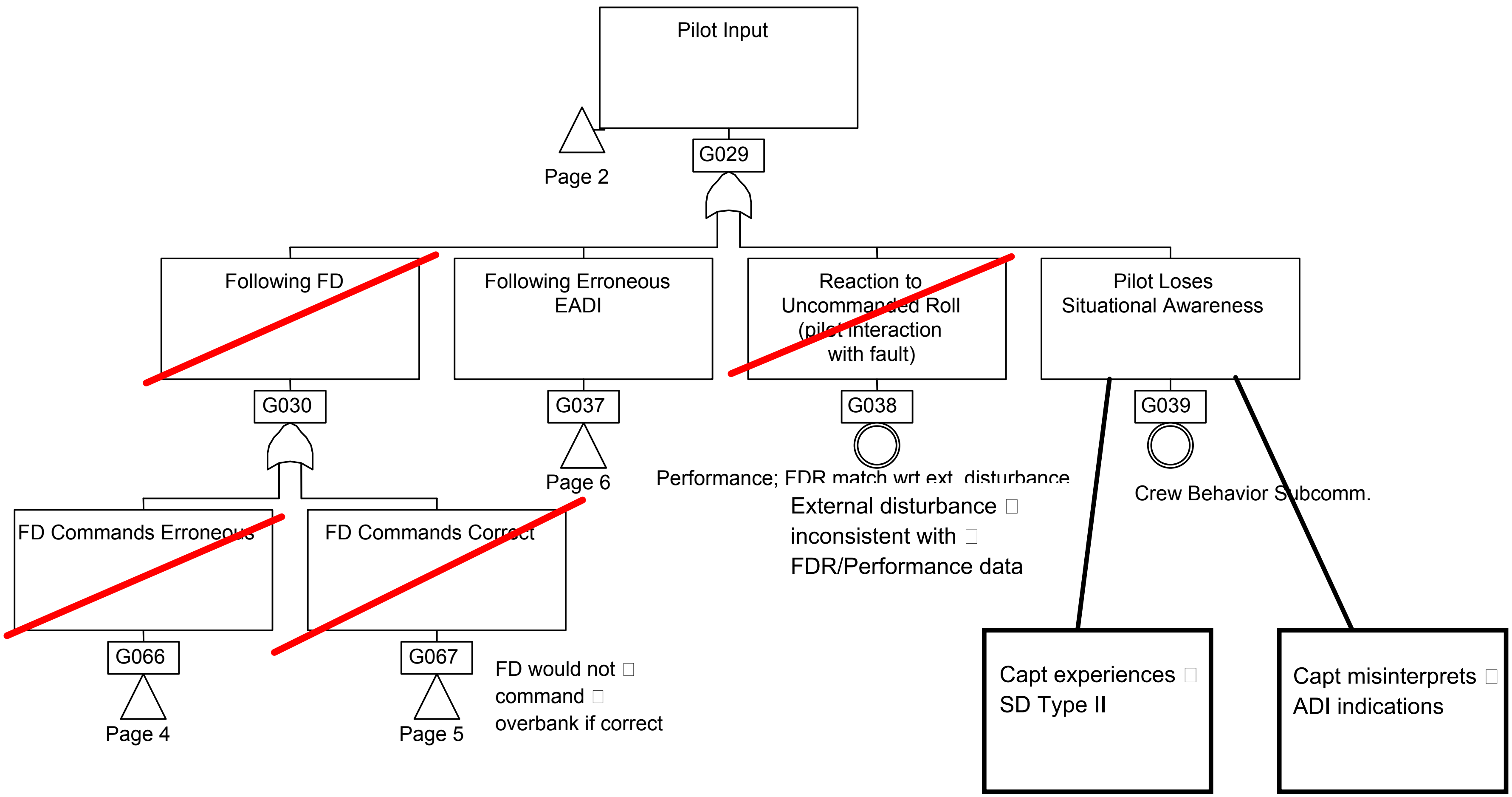
13.0 Right Roll Continues to Overbank with Aileron Activity



Cairo 4 Feb 05

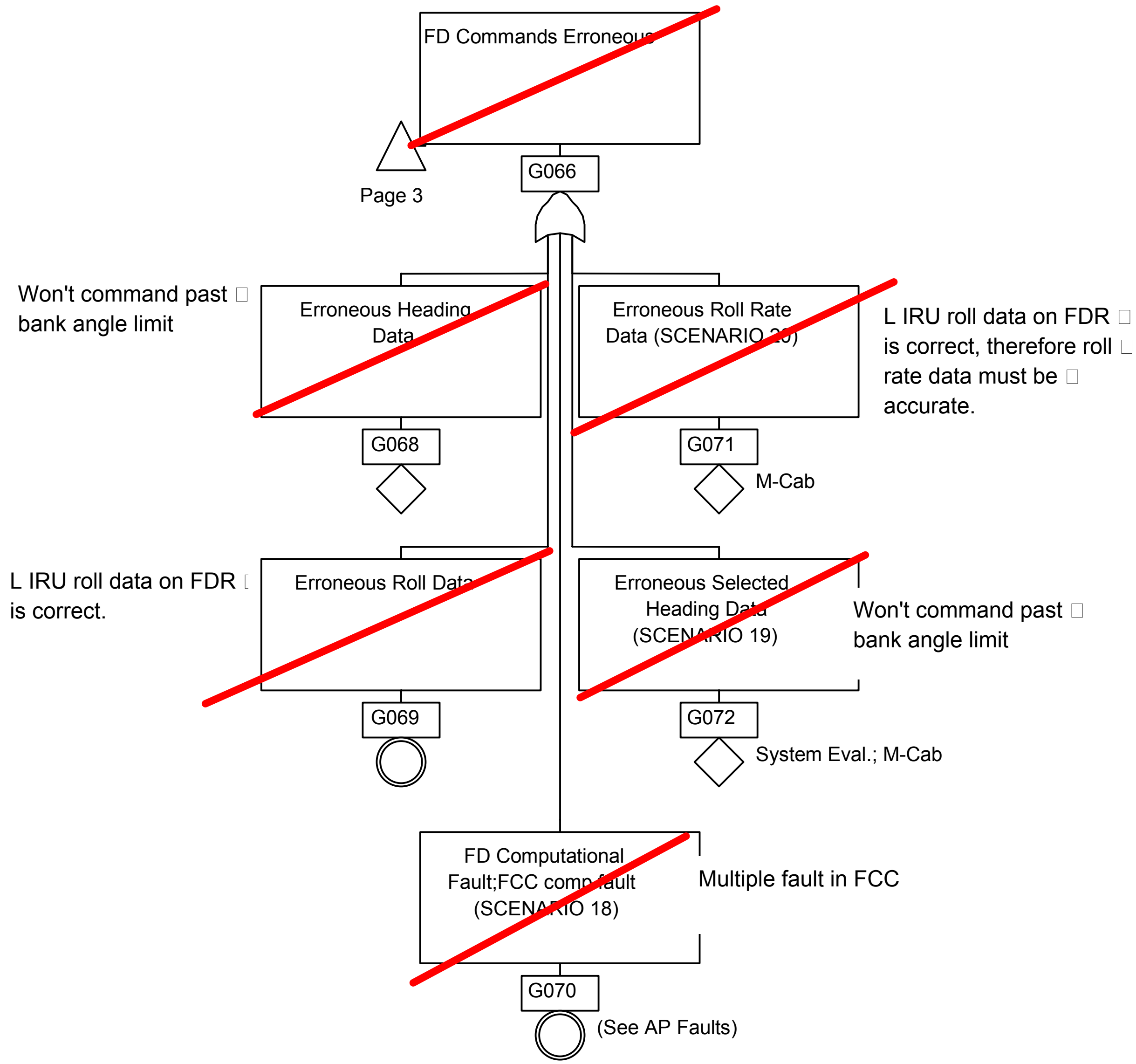
13.0 Right Roll Continues to Overbank with Aileron Activity

N.B.
For the "Lateral System Fault" block, See Appendix 2-1 lateral control analysis



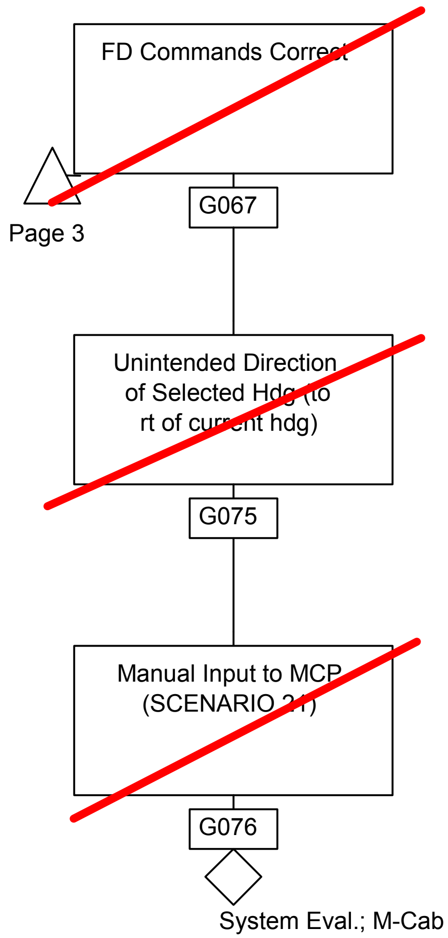
Cairo 26 Aug 05

13.0 Right Roll Continues to Overbank with Aileron Activity

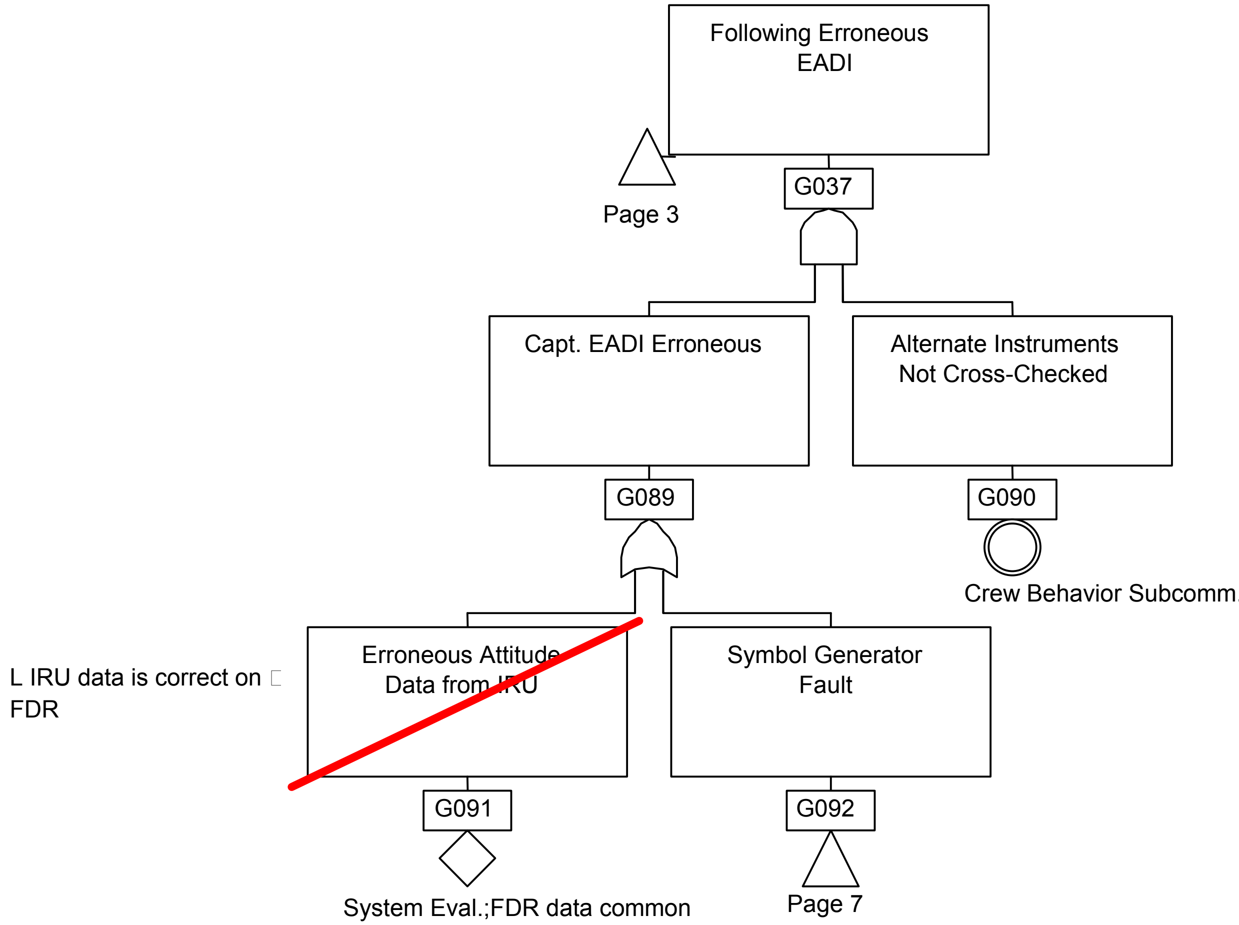


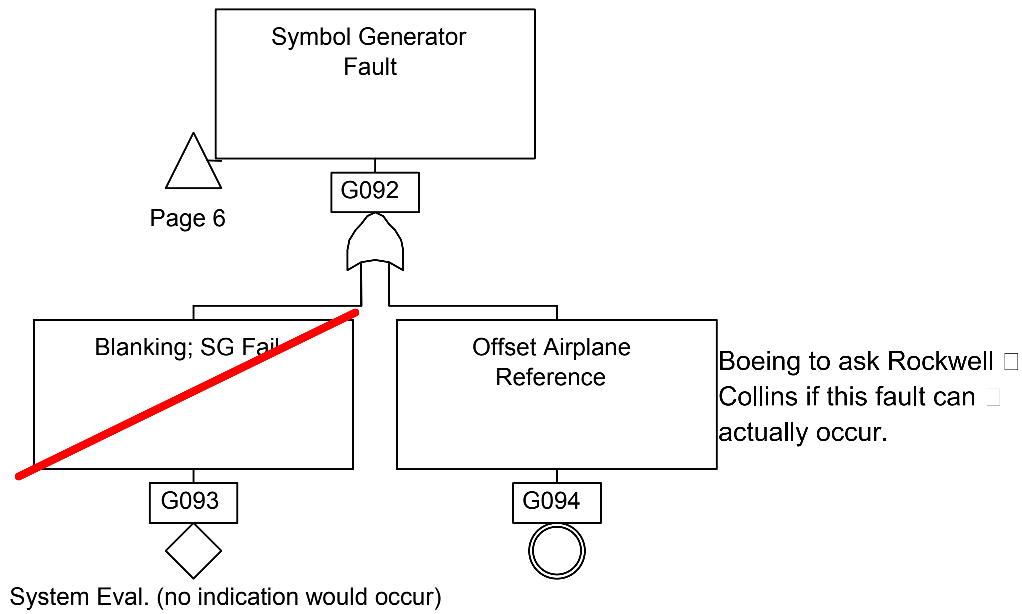
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



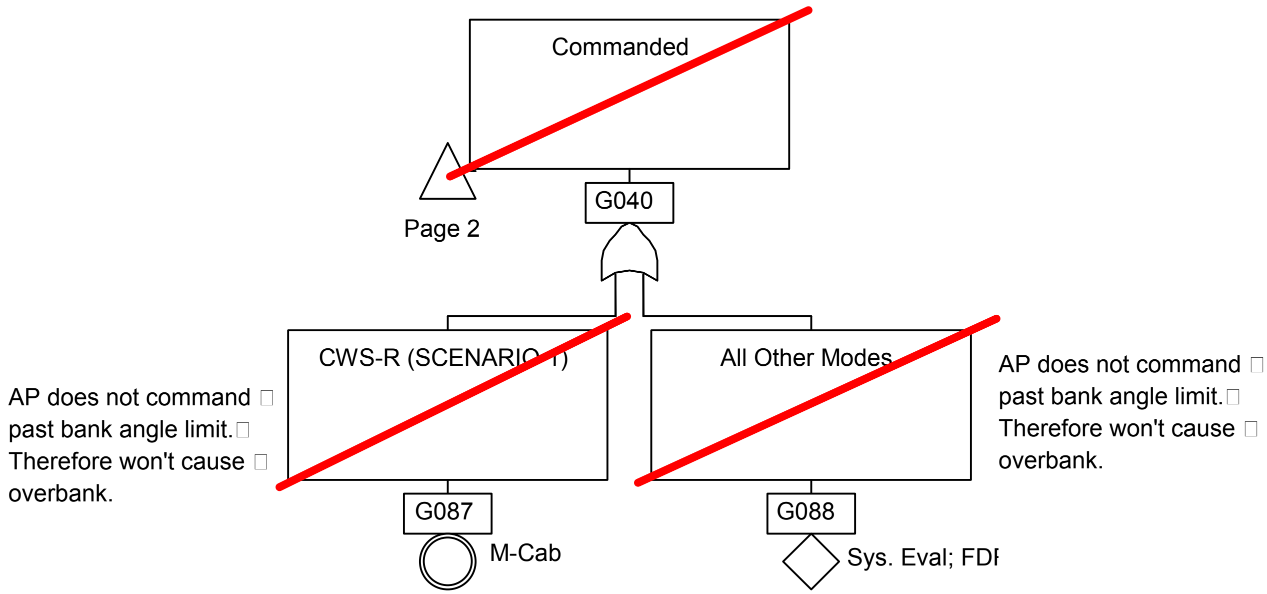
13.0 Right Roll Continues to Overbank with Aileron Activity


Following Erroneous EADI
Page 3
G037
Capt. EADI Erroneous
Alternate Instruments Not Cross-Checked
G089
G090
Crew Behavior Subcomm.
L IRU data is correct on FDR
Erroneous Attitude Data from IRU
Symbol Generator Fault
G091
G092
System Eval.;FDR data common
Page 7



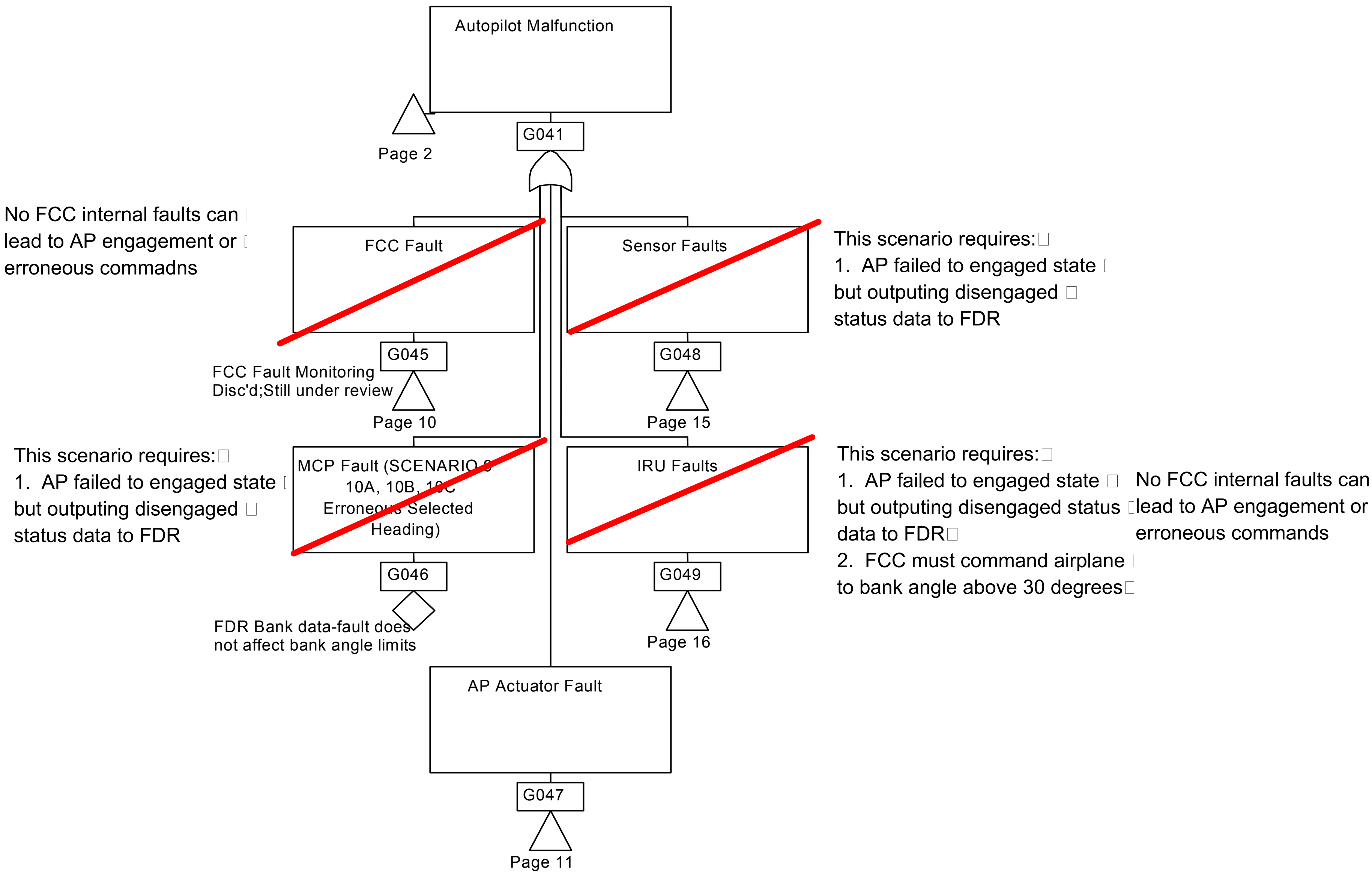
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity

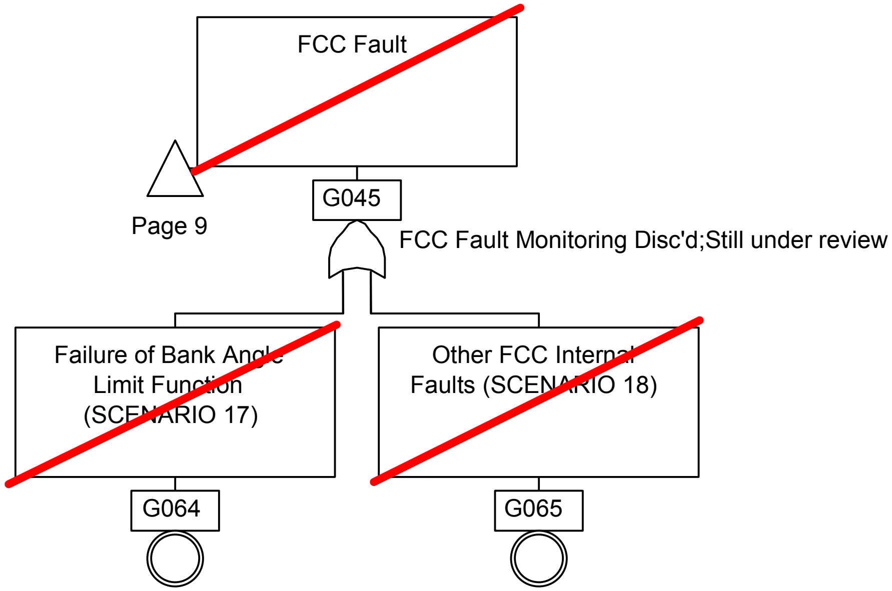


Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity

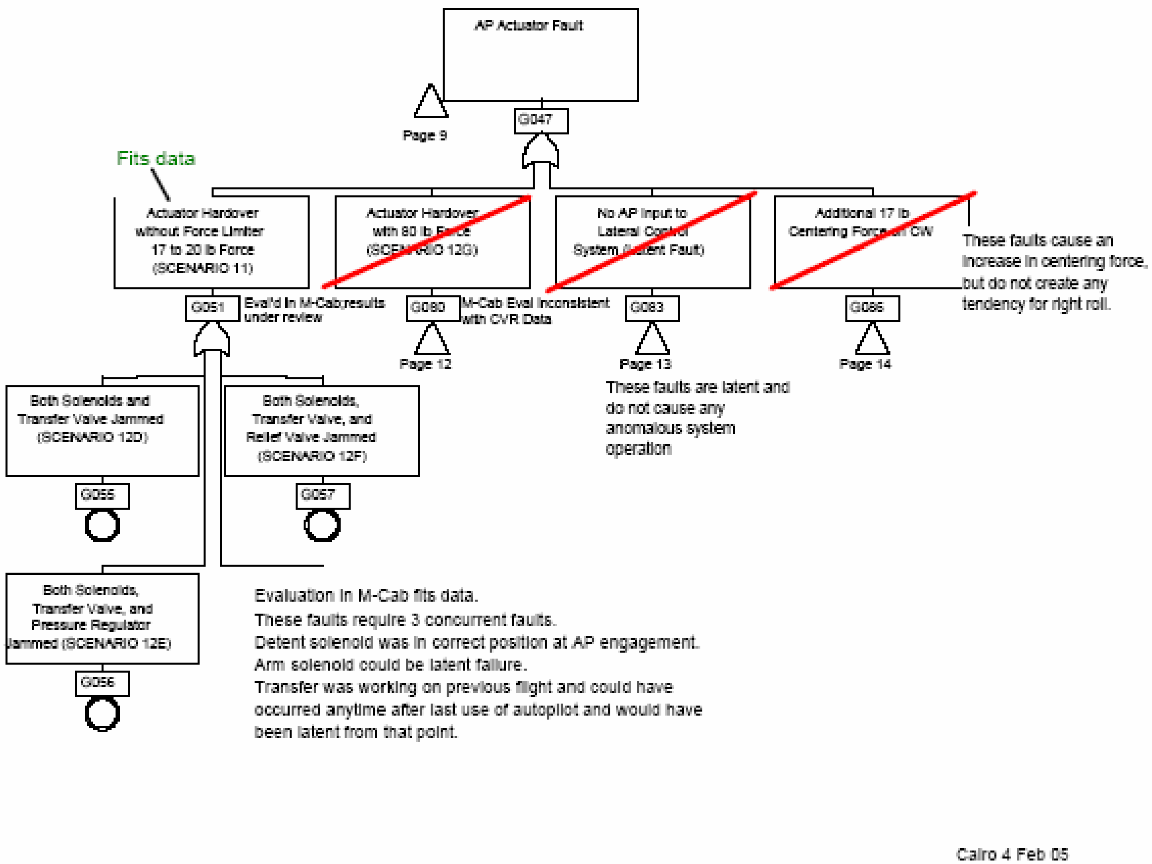


13.0 Right Roll Continues to Overbank with Aileron Activity



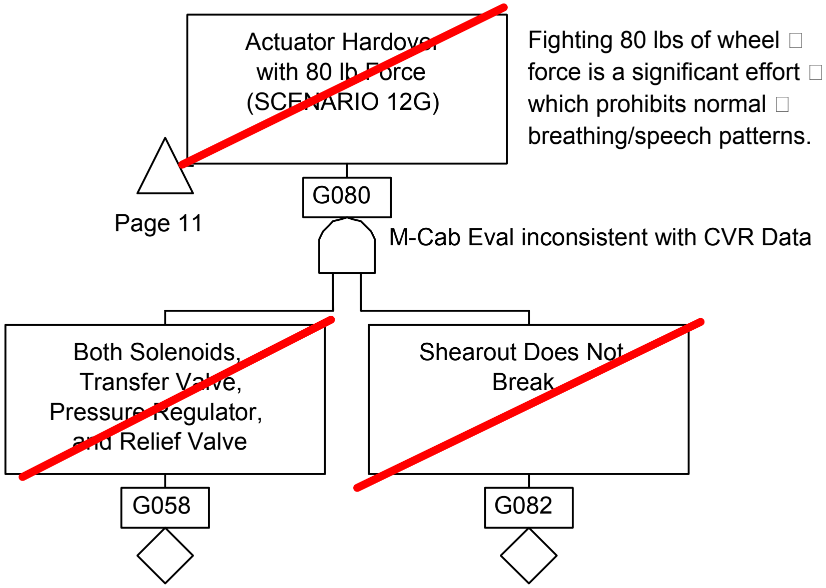
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



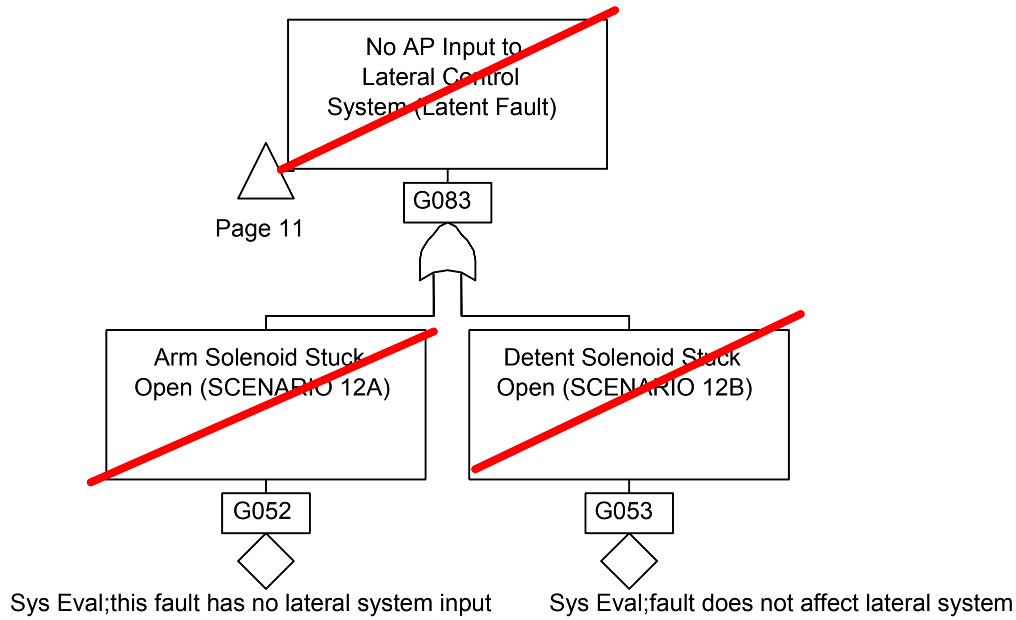
13.0 Right Roll Continues to Overbank with Aileron Activity

N.B.
For the “Actuator Hardover without Force Limiter 17 to 20 lb Force (SCENARIO 11)” block, See Appendix 2-1 lateral control analysis



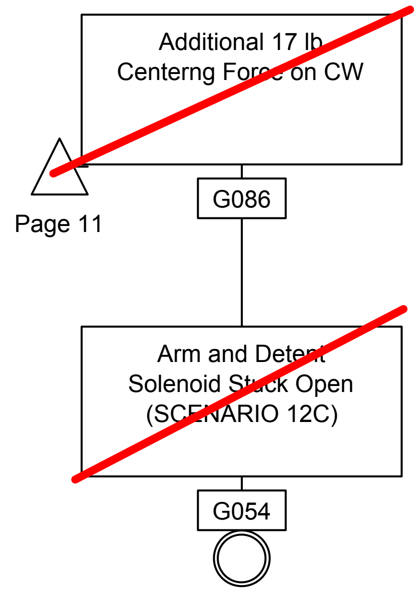
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



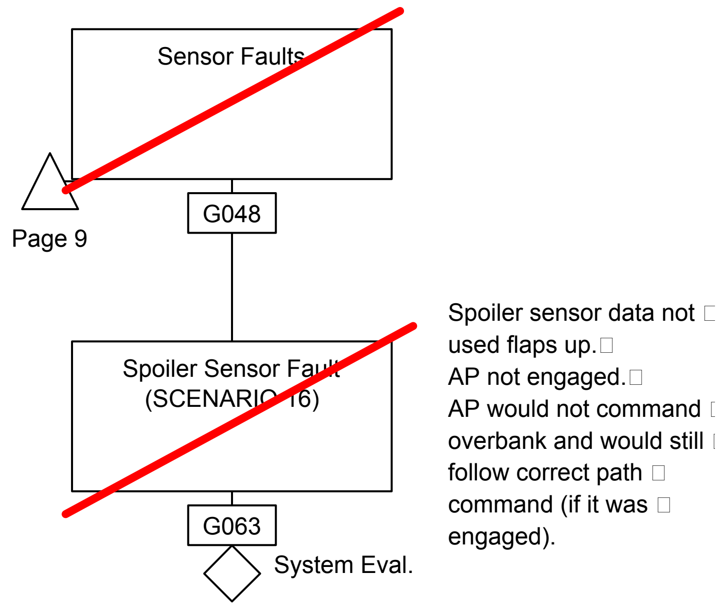
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity

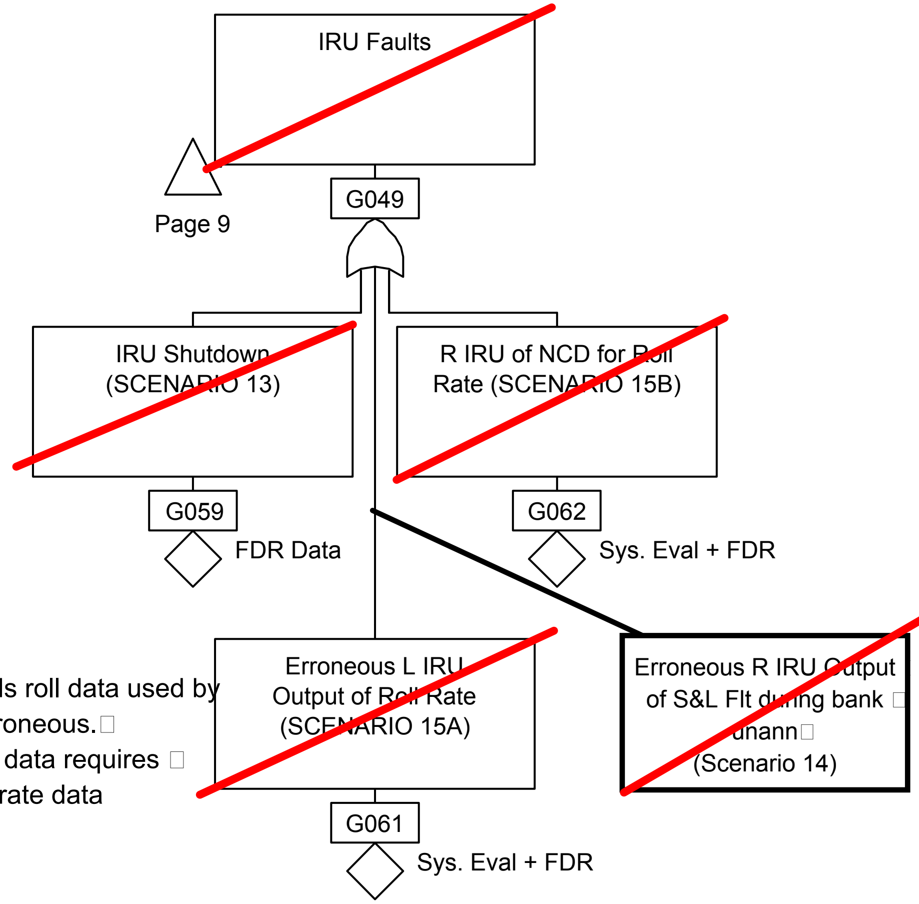


Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



13.0 Right Roll Continues to Overbank with Aileron Activity

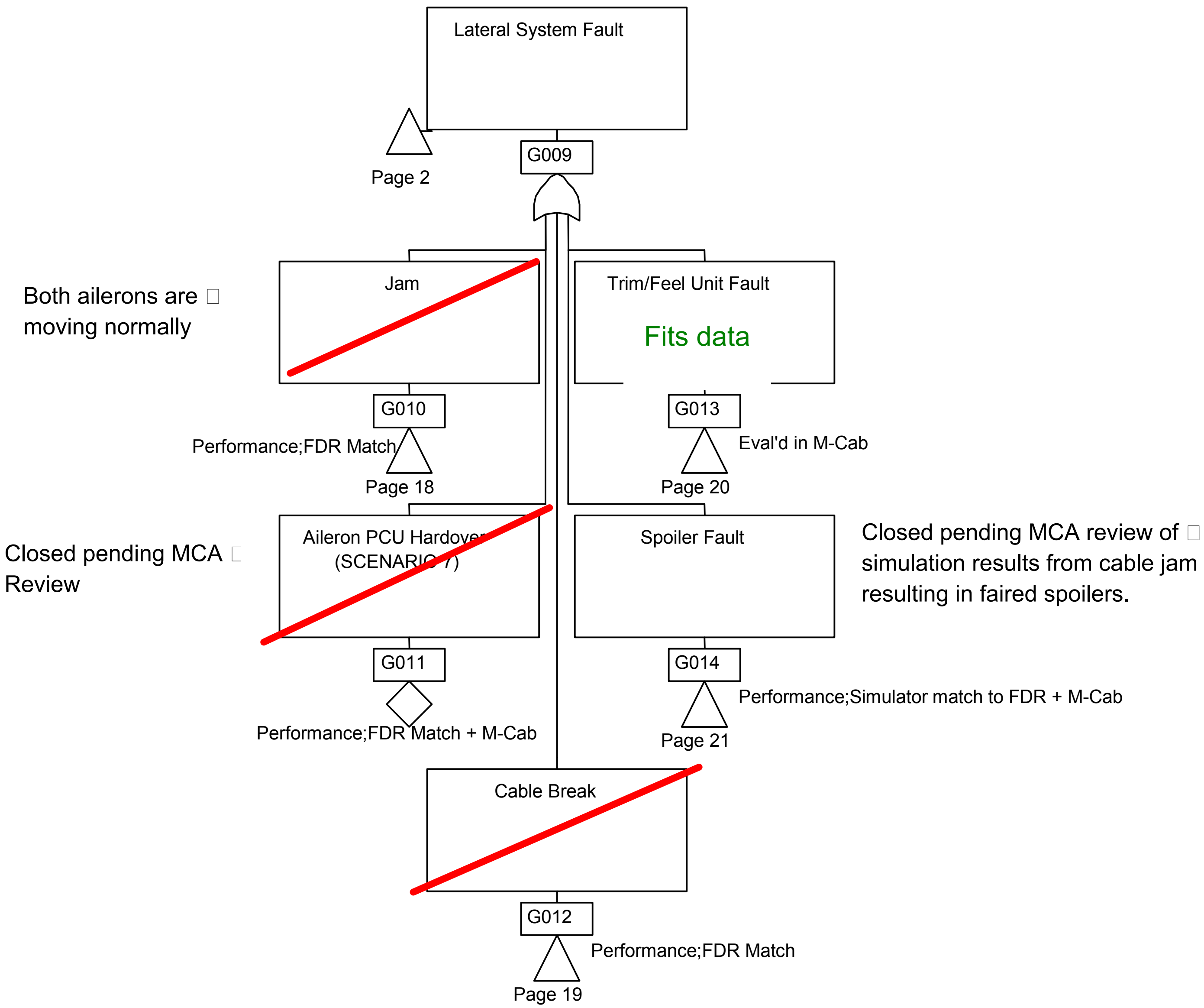


FDR records roll data used by FD - not erroneous.
Correct roll data requires correct roll rate data

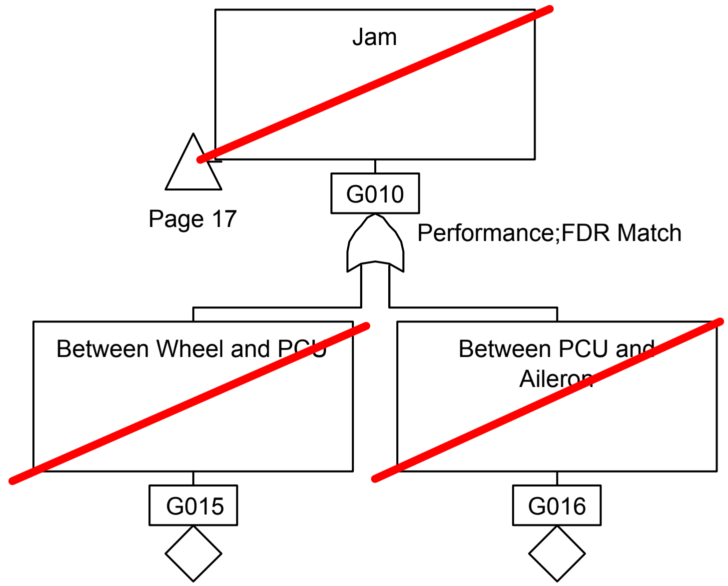
This scenario requires-
1 AP failed to engaged state but outputing disengaged status data to FDR.
2 Internal faults within IRU that allow incorrect roll data to be transmitted to FCC, EADI

Would result in:
1 AP actuator hardover.
2 Capt FD would provice correct steering cues
3 FO EADI would display S&L flight
("Overbank annunciations must therefore be based on some other source")
4 FO FD would display erroneous steering cues
5 Roll comparator annunciated

13.0 Right Roll Continues to Overbank with Aileron Activity

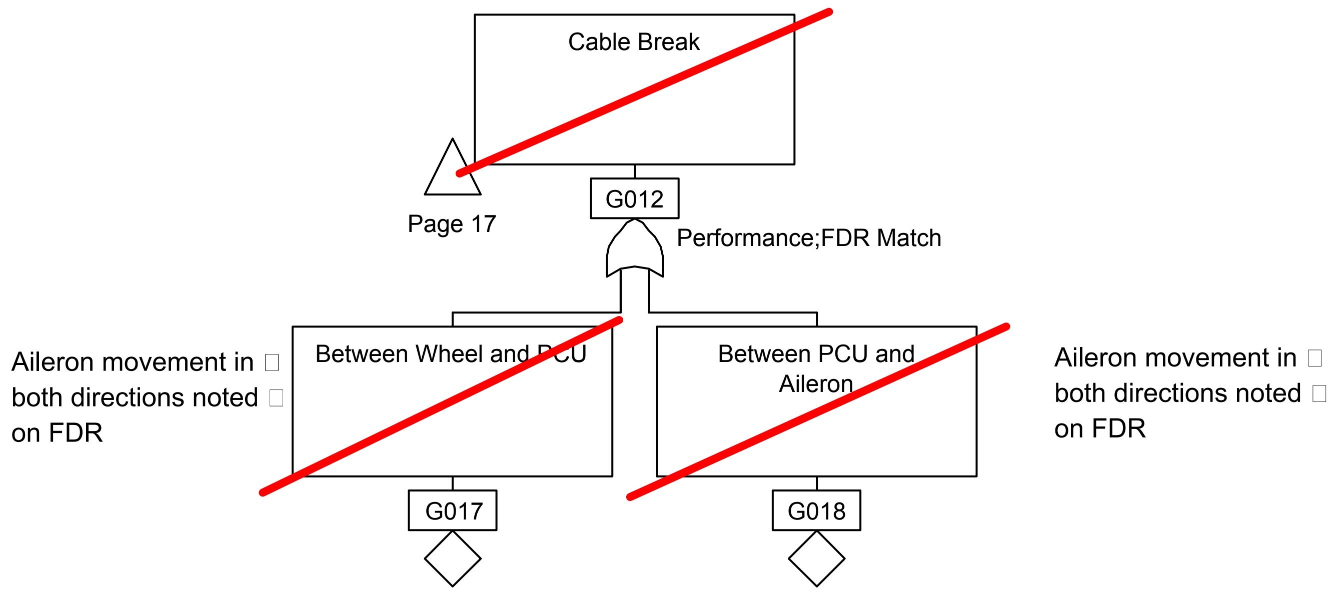


13.0 Right Roll Continues to Overbank with Aileron Activity



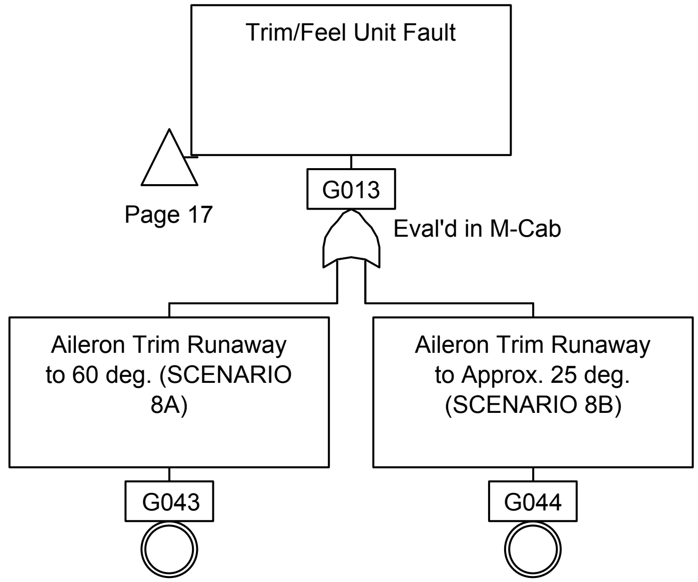
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



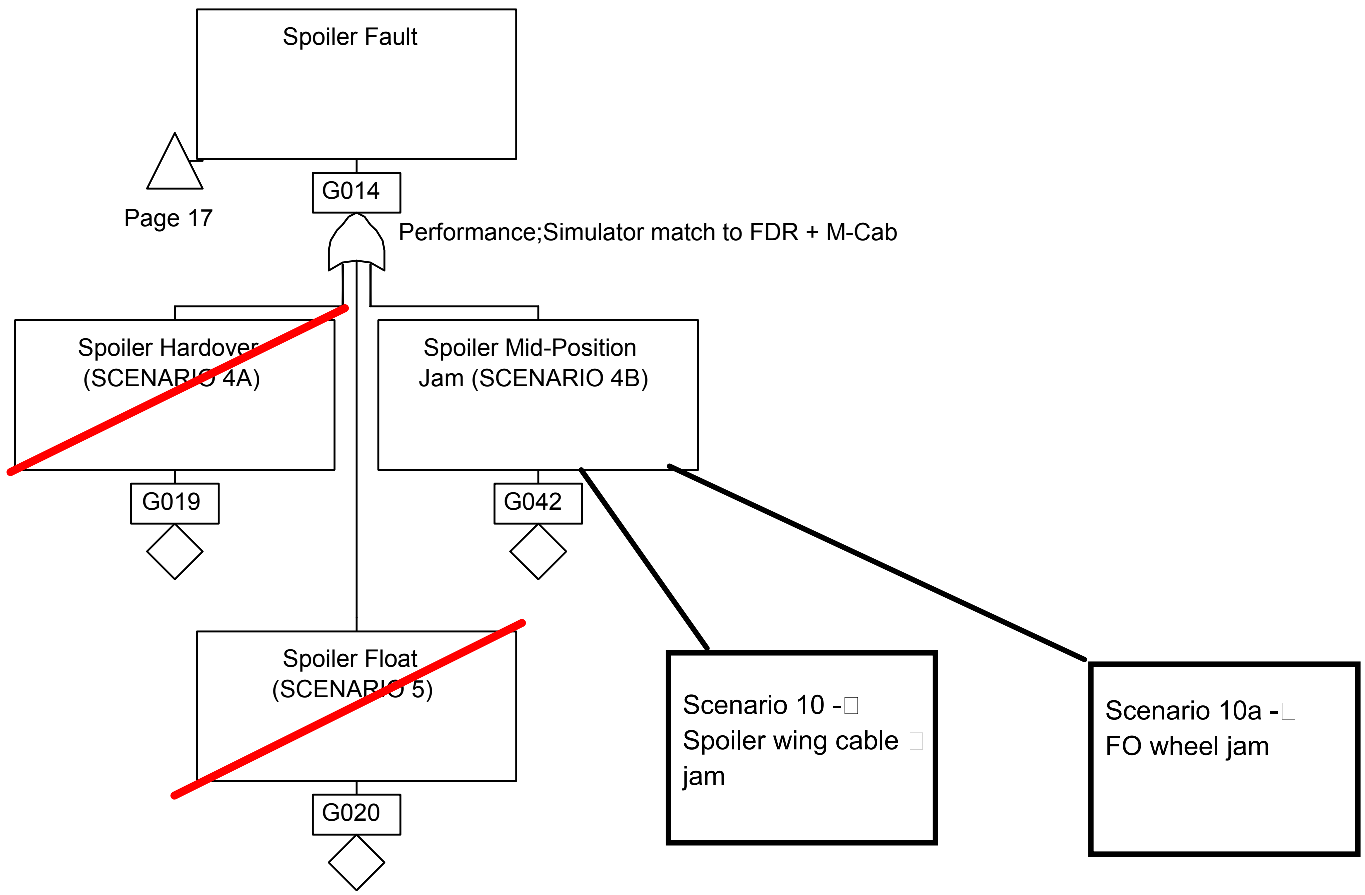
Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity



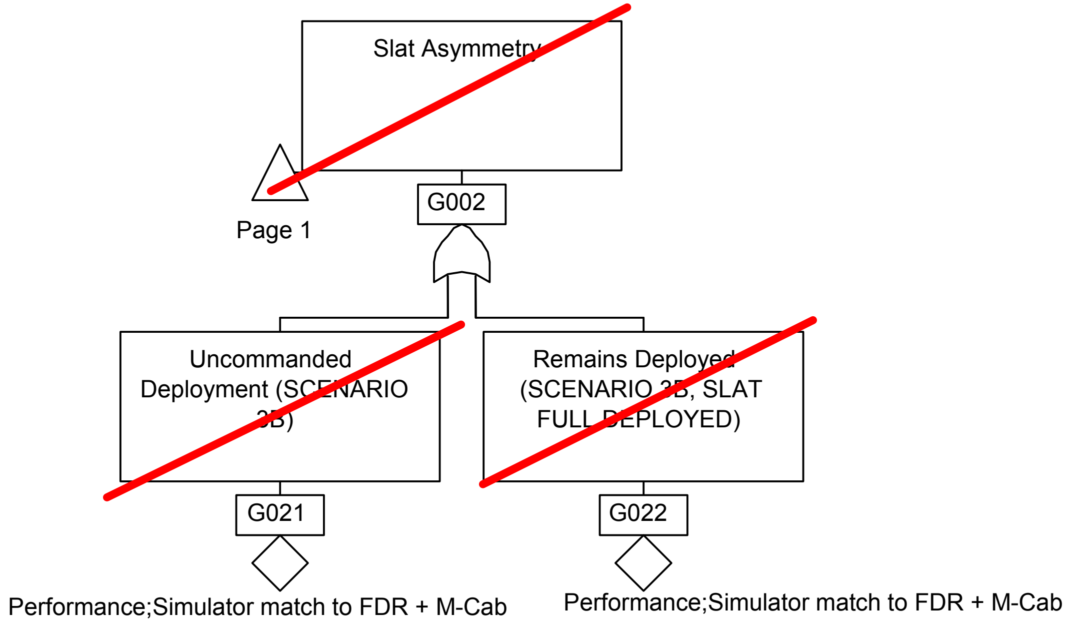
Evalutation in M-Cab fits data.
However, trim fault must have
occurred after autopilot engagement
(zero force, zero aileron engagement
indicates zero trim at that point).

Review ROV videos for trim actuator.



Cairo 26 Aug 05

13.0 Right Roll Continues to Overbank with Aileron Activity



Cairo 4 Feb 05

13.0 Right Roll Continues to Overbank with Aileron Activity

2.5.14 Flight crew CVR autopilot announcements

The following Figure shows the related FDR and CVR events

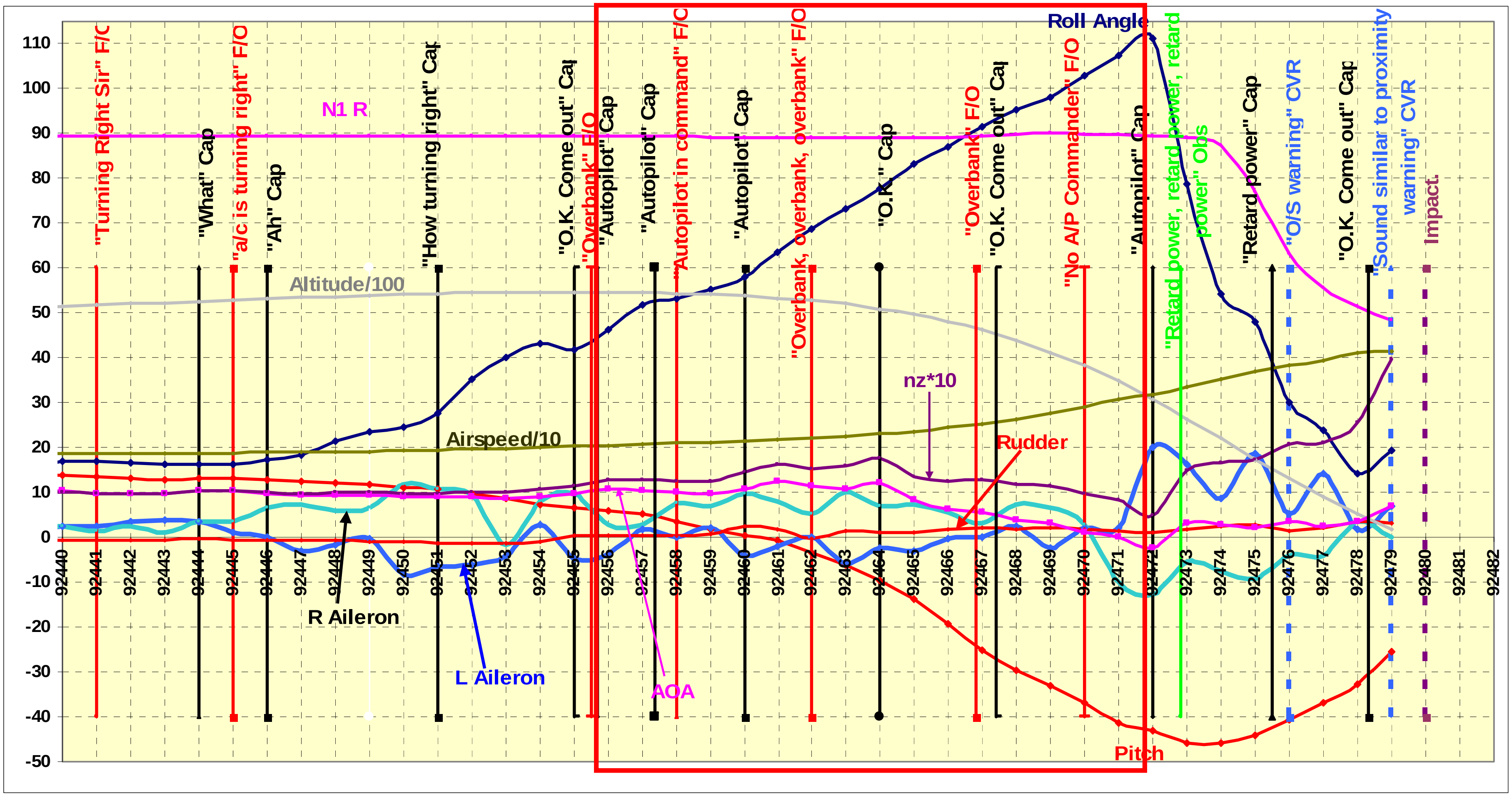


Figure 2.5.14.1 Flight crew CVR autopilot announcements

Flight crew CVR autopilot announcements might be explained by the following[1]:

1. Requests for Autopilot Engagement
   This scenario is consistent with expected normal airplane operation. If the Captain asked for autopilot and the F/O pressed the CMD button, the interlocks would not be satisfied because of forces on the control wheel. In this case, the button push is not recorded as an autopilot engagement on the FDR.
   (Done on M-Cab)

2. Announcement of Autopilot Status (Announcement of "Autopilot in Command" made by the F/O):
   This might be explained by one of the following possibilities:
   1. The statement was made automatic on button push without confirmation
   2. F/O thought autopilot was engaged
   3. F/O made mistake

3. Announcement of "No autopilot commander" made by the F/O:
   This announcement indicates that the F/O believed, to at least mean, that autopilot was not currently in operation.

4. Announcement of Perceived Autopilot Behavior

5. Requests for Autopilot Disengagement
   This condition requires perception on the part of the Captain that the autopilot is engaged

It is to be noticed that similar crew announcement occur during autopilot engagement near wings level. The evaluation of the comments here should take into account the meaning of the earlier announcements.

The investigation could not determine a higher possibility to any of the above conditions based on the given data.

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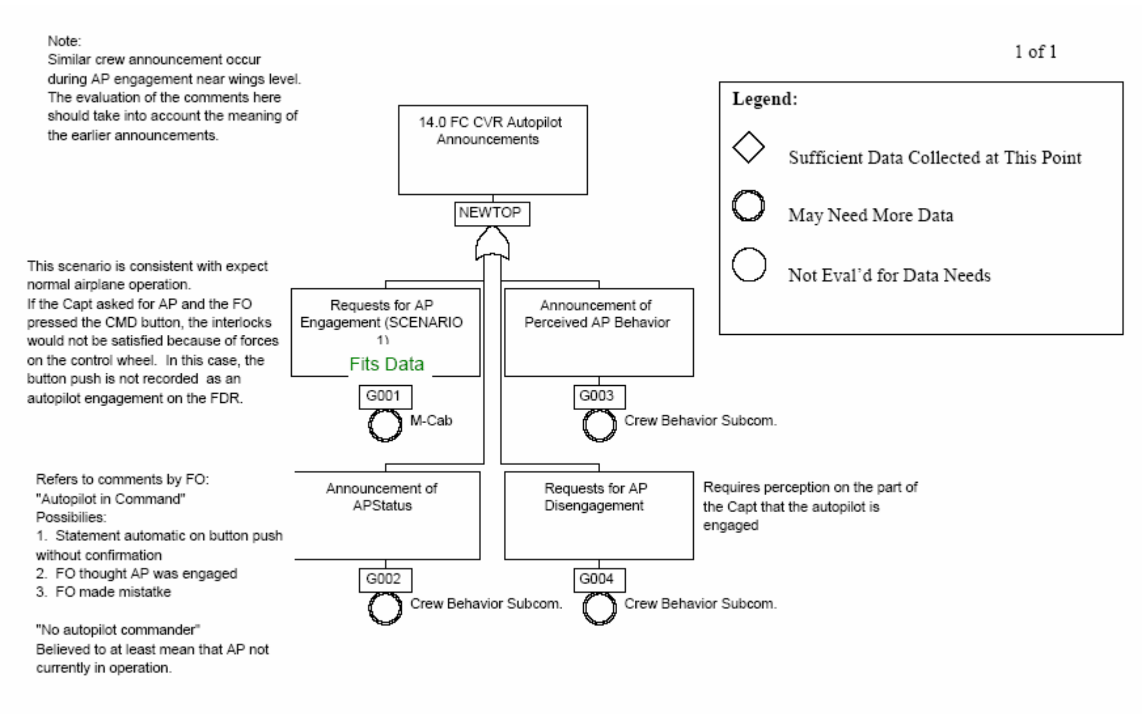
[1] See section 2.6 Human performance analysis


1 of 1
Note:
Similar crew announcement occur during AP engagement near wings level. The evaluation of the comments here should take into account the meaning of the earlier announcements.
14.0 FC CVR Autopilot Announcements
NEWTOP
Legend:
Sufficient Data Collected at This Point
May Need More Data
Not Eval'd for Data Needs
This scenario is consistent with expect normal airplane operation.
If the Capt asked for AP and the FO pressed the CMD button, the interlocks would not be satisfied because of forces on the control wheel. In this case, the button push is not recorded as an autopilot engagement on the FDR.
Requests for AP Engagement (SCENARIO 1)
Fits Data
G001
M-Cab
Announcement of Perceived AP Behavior
G003
Crew Behavior Subcom.
Refers to comments by FO:
"Autopilot in Command"
Possibilies:
1. Statement automatic on button push without confirmation
2. FO thought AP was engaged
3. FO made mistatke
"No autopilot commander"
Believed to at least mean that AP not currently in operation.
Announcement of APStatus
G002
Crew Behavior Subcom.
Requests for AP Disengagement
G004
Crew Behavior Subcom.
Requires perception on the part of the Capt that the autopilot is engaged

2.5.15 Rapid left roll towards wings level

The following figure shows the related FDR and CVR data

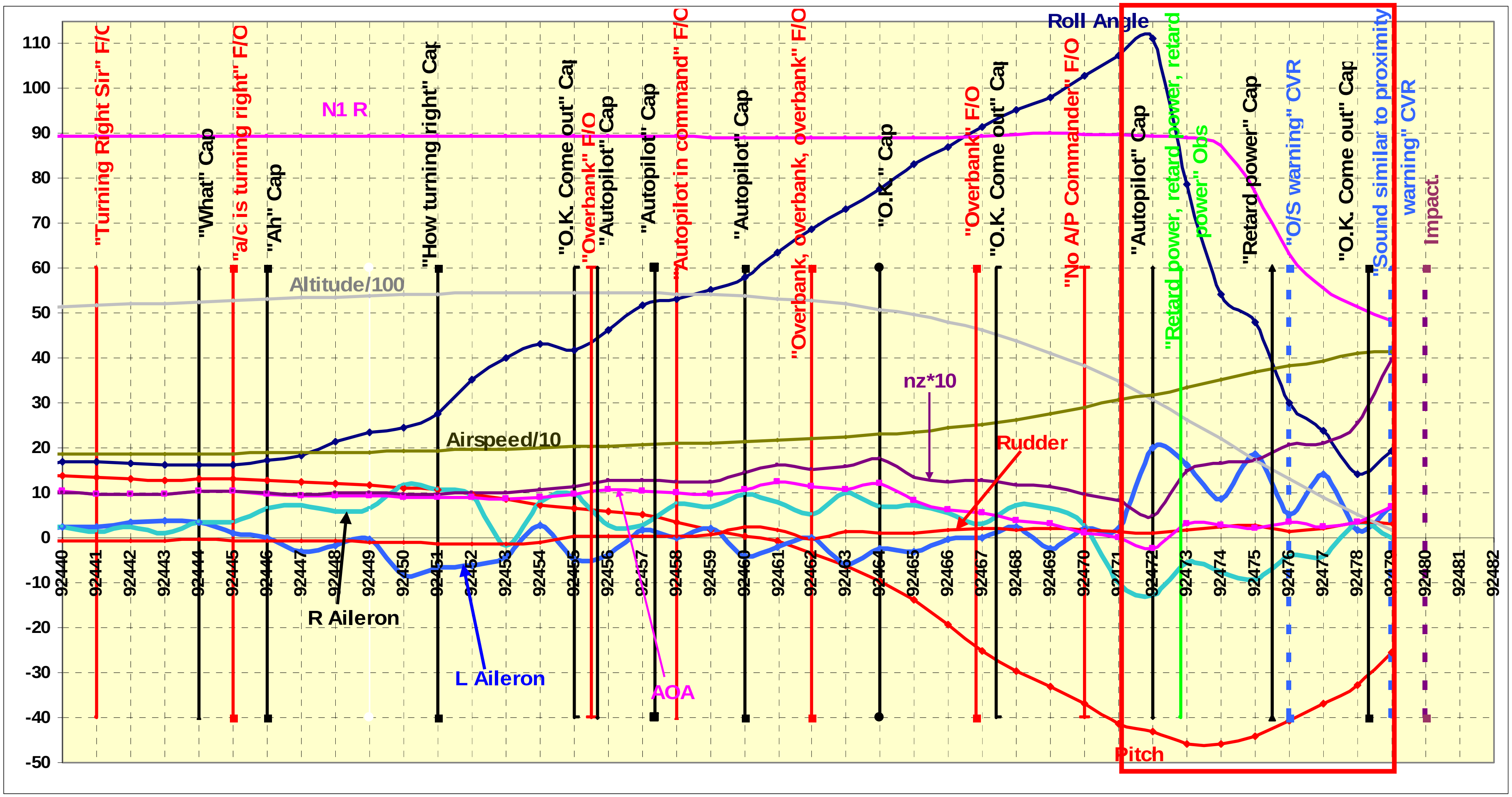


Figure 2.5.15 Rapid left roll towards wings level

The possibilties for this event are as follows:

1- Captain Upset Recovery Attempt
  - Captain Input Only
  - Captain in Presence of System Fault

This condition is supported by the information that the Captain was the pilot flying with nothing on CVR to suggest that control was transferred.
(Refer to section 2.6 Human Behavior, CBS report regarding CVR comments.)

2- First Officer Upset Recovery Attempt
  - First Officer Input Only
  - First Officer in Presence of System Fault

Based on CVR information, the FO did not announce that he is taking control.
(Refer to section 2.6 Human Behavior, CBS report regarding CVR comments.)

3- Joint Upset Recovery Attempt
  - Crew Input Only (Captain, F/O, & Observer)
  - Crew in Presence of System Fault (Captain, F/O, & Observer)

It is to be noted that previous upset events have resulted in multiple crew making control inputs; however the F/O does not announce he is taking control.

4- Lateral System Fault
  - PCU Fault
    - Based on the FDR data, the aileron motion recorded in both directions, even during recovery

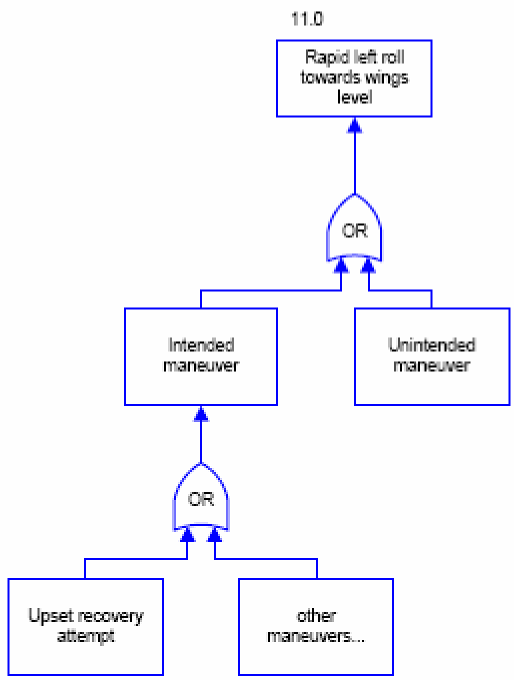
  - AP Actuator Fault
    - The aileron was commanded beyond A/P actuator limit (60 degrees of aileron wheel)

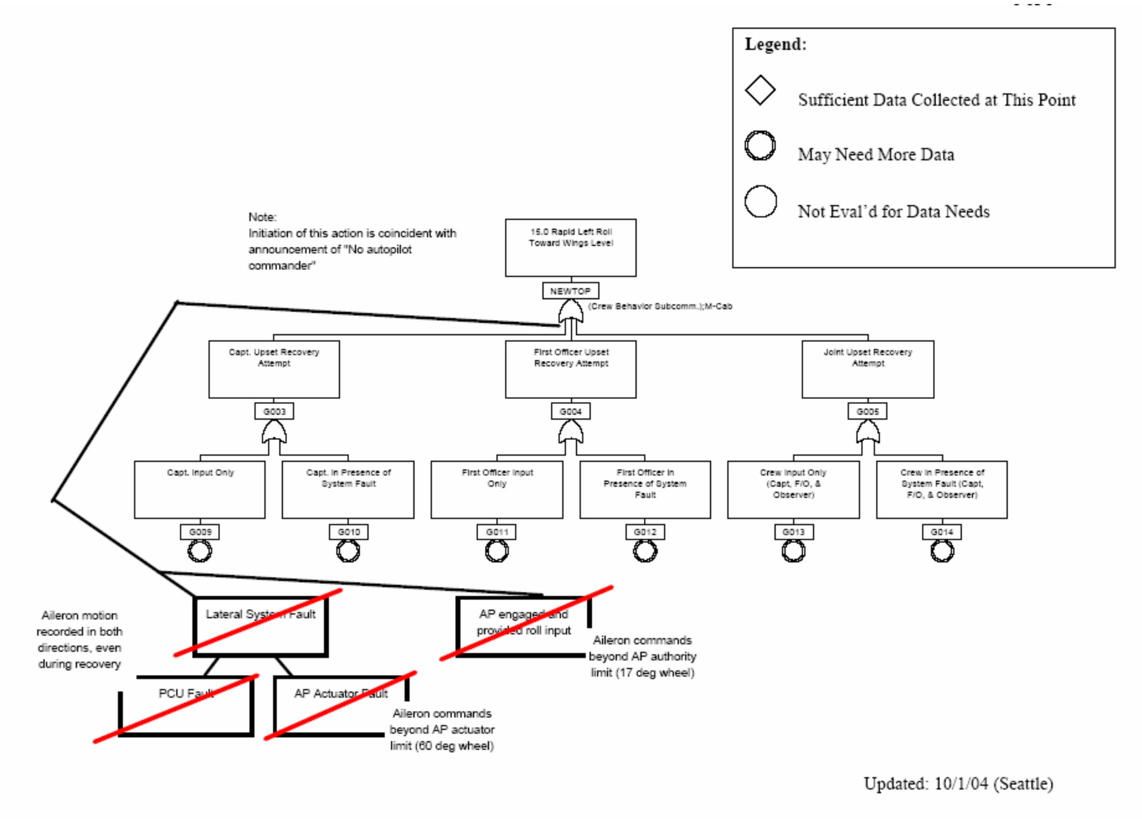
5- AP engaged and provided roll input
  - The aileron was commanded beyond A/P authority limit (17 degrees of aileron wheel)

Note:
Initiation of this event is coincident with announcement of "No autopilot commander"

Conditions 4 and 5 might be ruled out.

From the above, Captain Upset Recovery Attempt seems a higher possibility


11.0
Rapid left roll towards wings level
OR
Intended maneuver
Unintended maneuver
OR
Upset recovery attempt
other maneuvers...


Legend:
Sufficient Data Collected at This Point
May Need More Data
Not Eval'd for Data Needs
Note:
Initiation of this action is coincident with announcement of "No autopilot commander"
15.0 Rapid Left Roll Toward Wings Level
NEWTOP
(Crew Behavior Subcomm.);M-Cab
Capt. Upset Recovery Attempt
First Officer Upset Recovery Attempt
Joint Upset Recovery Attempt
G003
G004
G005
Capt. Input Only
Capt. In Presence of System Fault
First Officer Input Only
First Officer In Presence of System Fault
Crew Input Only (Capt, F/O, & Observer)
Crew In Presence of System Fault (Capt, F/O, & Observer)
G009
G010
G011
G012
G013
G014
Aileron motion recorded in both directions, even during recovery
Lateral System Fault
AP engaged and provided roll input
Aileron commands beyond AP authority limit (17 deg wheel)
PCU Fault
AP Actuator Fault
Aileron commands beyond AP actuator limit (60 deg wheel)
Updated: 10/1/04 (Seattle)

2.5.16 Impact with water

The impact occurred at about 92480 (02:45:06 GMT) with the following conditions:

Bank Angle	24.6˚ to the right
Pitch Angle	24˚ Nose down
Vertical G. Load	3.9
Speed	416 Kts

Although an attempt to correct the recovery was initiated, the gravity of the upset condition with regards to attitude, altitude and speed made this attempt insufficient to achieve a successful recovery.

Appendix 2-1 lateral control system analysis

Lateral Control System analysis:

The following table contains several hypothetical failure scenarios within the ailerons and spoilers control systems. The table also shows the consequences of the failures and the ability to control the airplane from either pilot's side.
The objective of this analysis is to exclude all the hypothetical failure scenarios that will not lead to the event (aileron movement causing airplane Overbank, with recorded aileron movements in both directions) and consider the other remaining failure scenarios which could lead to the event.

Table 1: Hypothetical single failures scenarios (Ailerons/ Spoilers Systems)

Ser.	Failed Component	Type of Failure	Input from Captain	Input from F/O	
1	Hydraulic sys tem A	System Failure	Captain will be able to drive the ailerons in both directions. Because the aileron PCUs are significantly oversized, aileron travel rates are not a function of hydraulic system availability - i.e. aileron travel rates are not significantly different whether either or both hydraulic systems are pressurized. For reference, the no load rate is approximately 54 degrees per second of aileron.[1] Spoilers 3, 6 will be lost. Operation of other spoilers will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: FLT Control A LOW PRESSURE light will illuminate, system low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant pumps LOW	F/O will be able to drive the ailerons in both directions. Because the aileron PCUs are significantly oversized, aileron travel rates are not a function of hydraulic system availability - i.e. aileron travel rates are not significantly different whether either or both hydraulic systems are pressurized. For reference, the no load rate is approximately 54 degrees per second of aileron. Spoilers 3, 6 will be lost Operation of other spoilers will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: FLT Control A LOW PRESSURE light will illuminate, system low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant	Does not match with failure scenario ***(closed)***

[1] Boeing letter B-H200-17833-ASI Dated 12 February 2004, Responses to Airplane System Queries

			PRESSURE lights will illuminate, hydraulic fault light on right light shield will illuminate.	pumps LOW PRESSURE lights will illuminate, hydraulic fault light on right light shield will illuminate.	
2	Hydraulic system B	System Failure	Captain will be able to drive the ailerons in both directions. Because the aileron PCUs are significantly oversized, aileron travel rates are not a function of hydraulic system availability - i.e. aileron travel rates are not significantly different whether either or both hydraulic systems are pressurized. For reference, the no load rate is approximately 54 degrees per second of aileron. Outboard Flight Spoilers 2, 7 will be lost Operation of other spoilers will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: FLT Control B LOW PRESSURE light will illuminate, system low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant pumps LOW	F/O will be able to drive the ailerons in both directions. Because the aileron PCUs are significantly oversized, aileron travel rates are not a function of hydraulic system availability - i.e. aileron travel rates are not significantly different whether either or both hydraulic systems are pressurized. For reference, the no load rate is approximately 54 degrees per second of aileron. Outboard Flight Spoilers 2, 7 will be lost Operation of other spoilers will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: FLT Control B LOW PRESSURE light will illuminate, system low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant pumps LOW	Does not match with failure scenario ***(closed)***

			PRESSURE lights will illuminate, hydraulic fault light on right light shield will illuminate.	PRESSURE lights will illuminate, hydraulic fault light on right light shield will illuminate.	
3	Both hydraulic systems A and B	Total Hydraulic Failure	Refer to the dual failure scenario table, case no. 1	Refer to the dual failure scenario table, case no. 1	Refer to table #2
4	One aileron control bus cable (ACBA, ACBB)	Broken Cable	Captain can still control ailerons and spoilers normally. Ailerons operation will not be affected in both directions Spoilers operation will not be affected in both directions. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. F/O wheel will simultaneously follow Captain wheel in one direction. In the opposite direction, it will follow the Captain wheel but after 12 degree of captain wheel movement. Aileron trim will operate normally Indication: No cockpit light indication	F/O will be able to drive the ailerons in one direction only Spoilers operation will be normal in one direction. The spoilers will respond only after 12 degrees of aileron control wheel rotation in the opposite direction (affected side) The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Captain wheel will simultaneously follow the F/O wheel in only one direction. Captain wheel will not follow the F/O wheel in the opposite direction Aileron trim will operate normally Indication: No cockpit light indication	Does not match with failure scenario ***(closed)***
5	One aileron control bus cable (ACBA, ACBB)	Jammed Cable at certain position	Captain wheel will jam at a position relative to the cable jammed position. Captain will not be able to drive neither the ailerons nor the spoilers. The ailerons will jam at a position relative the cable jammed	F/O will not be able to control the ailerons. The ailerons will jam at a position relative the cable jammed position. .At no load condition, the F/O control wheel will stay at a position relative to the cable jammed position.	Does not match with failure scenario (***Closed)***

			position. Aileron trim will be lost. Indication: No cockpit light indication	After 12 degrees of control wheel rotation, the spoilers will respond to the position of the control wheel. The F/O will have to overcome both the torsion spring torque (at the transfer mechanism) and the aileron spring cartridge before further rotation of the control wheel. Captain wheel will stay jammed and will not follow the F/O wheel Aileron trim will be lost. Indication: No cockpit light indication	
6	Captain aileron control bus drum	Control bus drum jammed	Similar to item 5	Similar to item 5	Does not match with failure scenario ***(Closed)***
7	Captain aileron control drum	Control drum jammed	Similar to item 5	Similar to item 5	Does not match with failure scenario ***Closed***
8	F/O aileron control bus drum	Control bus drum jammed	Similar to item 5	Similar to item 5	Does not match with failure scenario ***(Closed)***
9	Spoiler control drum	Spoiler control drum jammed in the center	The captain will be able to control the ailerons as much as 12 degrees in either direction from the	The F/O aileron control wheel will be limited to 12 degrees either directions (motion will only be	Does not match with failure scenario ***(Closed)***

		(neutral) position	jammed position with normal feel forces. Beyond 12 degrees, an additional force is required to overcome the transfer mechanism and the aileron spring cartridge. The flight spoilers will remain in the position corresponding to the position of the jammed spoiler control drum, irrespective of any mechanical inputs from either control wheel (faired position). F/O aileron control wheel will follow the Captain aileron control wheel only in the range of 12 degrees either side of the position at which the spoiler control drum is jammed. After that movement of Captain aileron control wheel, the F/O aileron control wheel will not follow the Captain aileron control wheel. Aileron trim will be available in the range of 12 degrees either side of the position at which the spoiler control drum is jammed (the centering spring is not strong enough to overcome the transfer mechanism). Indication:	limited to the lost motion gap between the lost motion device crank and the lost motion lug).Therefore, the F/O will be able to control the ailerons only within 12 degrees of aileron control wheel rotation in either direction. The flight spoilers will remain in the position corresponding to the position of the jammed spoiler control drum, irrespective of any mechanical inputs from either control wheel (faired position). Captain aileron control wheel will follow the F/O aileron control wheel during its restricted movement (range of 12 degrees either side of the position at which the spoiler control drum is jammed). Aileron trim will be available in the range of 12 degrees either side of the position at which the spoiler control drum is jammed (the centering spring is not strong enough to overcome the transfer mechanism). Indication: No cockpit light	

			No cockpit light indication	indication	
10	Spoiler control drum	Spoiler control drum jammed offset from the center (neutral) position	The spoiler control drum will jam the lost motion device crank offset of the neutral position. The centering spring at the trim unit will pull both control wheels up to 12 degrees towards center through the lost motion device range. The centering spring is not strong enough to overcome the transfer mechanism. As a result, the ailerons and control wheel will remain 12 degrees from the jammed position (at no load condition on the control wheels), or at center if the jammed position is less than 12 degrees. The flight spoilers will remain in the position corresponding to the position of the jammed spoiler control drum, irrespective of any mechanical inputs from either control wheel. The captain will be able to control the ailerons as much as 12 degrees in either direction from the jammed position with normal feel forces. Beyond 12 degrees, an additional force is required to overcome the transfer	The spoiler control drum will jam the lost motion device crank offset of the neutral position. The centering spring at the trim unit will pull both control wheels up to 12 degrees towards center through the lost motion device range. The centering spring is not strong enough to overcome the transfer mechanism. As a result, the ailerons and control wheel will remain 12 degrees from the jammed position (at no load condition on the control wheels), or at center if the jammed position is less than 12 degrees. The flight spoilers will remain in the position corresponding to the position of the jammed spoiler control drum, irrespective of any mechanical inputs from either control wheel. The F/O will be able to control the ailerons as much as 12 degrees in either direction from the jammed position with normal feel forces. F/O wheel motion will be limited to 12 degrees either direction from the	Simulation has been done by Boeing. Refer to Chapter 2 Analysis

			mechanism and the aileron spring cartridge. Aileron trim will be available in the range of 12 degrees either side of the position at which the spoiler control drum is jammed. Indication: No cockpit light indication	jammed position. Aileron trim will be available in the range of 12 degrees either side of the position at which the spoiler control drum is jammed. Indication: No cockpit light indication	
10a	F/O control wheel shaft	F/O control wheel shaft jammed at a position offset of the neutral position	The F/O aileron control wheel will jam at a position offset of the neutral position relevant to the position of the jammed shaft. The centering spring at the trim unit will not be able to re-center the Captain aileron control wheel because of the resistance of the override mechanism strong torsion spring. Therefore, the Captain wheel will stay at the same position as the F/O aileron control wheel whenever the Captain aileron control wheel is released The captain will be capable of controlling the ailerons from his side, but with an additional force to overcome the override mechanism torsion spring. The ailerons will always follow the aileron control wheel. The spoilers will	The F/O aileron control wheel will jam at a position offset of the neutral position relevant to the position of the jammed shaft.	Simulation has been done by Boeing. Refer to Chapter 2 Analysis

			follow the captain aileron control wheel within only 12 degrees both sides from the offset wheel position. Input to the flight spoilers will be via the aileron spring cartridge. After 12 degrees of wheel rotation, the spoiler control drum lost motion lug will contact the lost motion device crank on the F/O control wheel shaft, preventing any further movement of the spoiler control drum. The spring cartridge will compensate for the continuing inputs from the ailerons bus drums. Indication: No cockpit light indication	Indication: No cockpit light indication	
11	Force Transducer	Broken force transducer	Captain will still be able to normally control the ailerons and spoilers from the Captain aileron control wheel. (Movement from the aileron control bus drum will be transmitted to the aileron drum through the mechanical stops on both drums). F/O aileron control wheel will simultaneously follow the Captain control wheel. The ailerons will not be biased in any direction by the aileron control system	F/O will still be able to normally control the ailerons and spoilers from the F/O aileron control wheel. (Movement from the aileron control bus drum will be transmitted to the aileron drum through the mechanical stops on both drums). Captain aileron control wheel will simultaneously follow the F/O control wheel. The ailerons will not be biased in any direction by the aileron control system with the control wheel	Does not match with failure scenario ***(Closed)***

			with the control wheel at no load condition. Aileron trim will still be functional (Refer to autopilot failure analysis)	at no load condition. Aileron trim will still be functional (Refer to autopilot failure analysis)	
12	One aileron control cable (left side) (ACBA, ACBB)	Broken Cable	Captain will be able to drive the ailerons in one direction only (unaffected direction). Spoilers will operate normally in the unaffected direction with Captain aileron control wheel rotation, however, when the aileron wheel is rotated in the opposite direction (affected direction), spoilers will follow aileron control wheel only after 12 degrees of wheel rotation, with an additional force to overcome the spring cartridge. Aileron trim will be available in both directions. F/O aileron control wheel will simultaneously follow the Captain control wheel. The aileron wheel may be slightly offset from neutral position due to cable stretch in one side Indication: No cockpit light indication	F/O will be able to drive the ailerons in one direction only (unaffected direction). Spoilers will operate normally in the unaffected direction with F/O aileron control wheel rotation, however, when the aileron wheel is rotated in the opposite direction (affected direction), spoilers will follow aileron control wheel only after 12 degrees of wheel rotation, with an additional force to overcome the spring cartridge. Aileron trim will be available in both directions. Captain aileron control wheel will simultaneously follow the F/O control wheel. The aileron wheel may be slightly offset from neutral position due to cable stretch in one side Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***
13	One aileron control cable (left side) (ACBA, ACBB)	Jammed Cable	Captain wheel will jam at a position relevant to the cable jammed position. Captain will not be able to drive neither the ailerons nor the spoilers.	The ailerons will jam and remain at a position relevant to the cable jammed position. The spoilers will remain at the jammed position until F/O intervention.	Does not match with failure scenario ***(Closed)***

			The ailerons will jam and remain at a position relevant to the cable jammed position. The spoilers will remain at the jammed position until F/O intervention. Aileron trim will not be available. Indication: No cockpit light indication	F/O will have to overcome the torsion spring resistance in the transfer mechanism, to start rotating the aileron control wheel. After 12 degrees of control wheel rotation, the F/O will be able to drive the spoilers with additional force to overcome the spring cartridge. Captain wheel will not follow the movement of the F/O control wheel and will stay jammed at a position relevant to the cable jammed position Aileron trim will not be available Indication: No cockpit light indication	
14	Aileron control Quadrant	Quadrant jammed	Similar to case 13	Similar to case 13	Does not match with failure scenario ***(Closed)***
15	PCA input rod (A or B)	Jammed	Similar to case 13	Similar to case 13	Does not match with failure scenario ***(Closed)***
16	PCA input rod (A or B)	Broken	There is no functional effect of a single failure in the PCA input rod. The entire input rod and fasteners are dual load path. The effect of a multiple failure depends on the position of the primary slide at the time of the failure. Worst case	There is no functional effect of a single failure in the PCA input rod. The entire input rod and fasteners are dual load path. The effect of a multiple failure depends on the position of the primary slide at the time of the failure.	Does not match with failure scenario ***(Closed)***

			effect is a rate jam of the affected PCU, causing a force fight with the other PCU and stalling of both PCUs. During such a force fight, the captain's control wheel motion is available one direction only. The F/O aileron control wheel will simultaneously follow the Captain aileron control wheel in this direction. (Aileron and spoiler position will correspond to the position of the captain's control wheel). Under no load condition, the captain's control wheel will remain in its current position or may drift slightly depending upon tolerances within the PCUs. Aileron trim will not be available. In case of failure of input rod with both the	Worst case effect is a rate jam of the affected PCU, causing a force fight with the other PCU and stalling of both PCUs. During such a force fight, the captain's control wheel motion is available one direction only; therefore, the F/O will be able to rotate the F/O control wheel in this direction with no additional forces. The Captain aileron control wheel will simultaneously follow the F/O aileron control wheel. (Aileron position will correspond to the position of the captain's control wheel.) In the opposite direction, the F/O aileron control wheel will be opposed by the Captain wheel, however, the first officer's wheel can be moved be used to control the spoilers after overcoming the transfer mechanism. Under no load condition, the first officer's control wheel will remain in its current position or may drift slightly depending upon tolerances within the PCUs. Aileron trim will not be available.	

			primary and secondary valves staying at the center position, the affected PCU will be hydraulically locked by blocking both the extend and retract sides of the PCU. The affected PCU will jam the unaffected PCU causing jamming to the Captain aileron control wheel in both directions (because of the mechanical stops on the PCU input arms). Therefore, the Captain will not be able to control neither the ailerons nor the spoilers from his side. Depressurizing the affected PCU will restore normal control Indication: No cockpit light indication	In case of failure of input rod with both the primary and secondary valves staying at the center position, the affected PCU will be hydraulically locked by blocking both the extend and retract sides of the PCU. The affected PCU will jam the unaffected PCU causing jamming to the Captain aileron control wheel in both directions (because of the mechanical stops on the PCU input arms). Therefore, the Captain will not be able to control neither the ailerons nor the spoilers from his side. The first officer's wheel can be moved be used to control the spoilers after overcoming the transfer mechanism in both directions. Depressurizing the affected PCU will restore normal control Indication: No cockpit light indication.	
17	Primary slide valve	Primary slide valve jammed offset of neutral position on one PCU	1. If the primary slide and secondary slide jam together near neutral, the effect is a minor reduction in rate capability. 2. If the jam occurs away from neutral, the feedback motion of the PCU will cause	1. If the primary slide and secondary slide jam together near neutral, the effect is a minor reduction in rate capability. 2. If the jam occurs away from neutral, the feedback motion of the PCU will cause	Does not match with failure scenario ***(Closed)***

			the primary and secondary slides to counter each other (crossflow condition). At a full crossflow condition, the PCU will lose rate capability and be backdriven by the unaffected PCU. Normal control of the ailerons and spoilers is available (latent failure). Aileron trim is not affected. Indication: No cockpit light indication	the primary and secondary slides to counter each other (crossflow condition). At a full crossflow condition, the PCU will lose rate capability and be backdriven by the unaffected PCU. Normal control of the ailerons and spoilers is available (latent failure). Aileron trim is not affected. Indication: No cockpit light indication	
18	Secondary slide valve	Secondary slide valve jammed	1. If the secondary slide jams near neutral, the effect is a minor reduction in rate capability. 2. If the jam occurs away from neutral, the feedback motion of the PCU will cause the primary and secondary slides to counter each other (crossflow condition). At a full crossflow condition, the PCU will lose rate capability and be backdriven by the unaffected PCU. Normal control of the ailerons and spoilers is available. Aileron trim is not affected. Indication: No cockpit light indication	1. If the secondary slide jams near neutral, the effect is a minor reduction in rate capability. 2. If the jam occurs away from neutral, the feedback motion of the PCU will cause the primary and secondary slides to counter each other (crossflow condition). At a full crossflow condition, the PCU will lose rate capability and be backdriven by the unaffected PCU. Normal control of the ailerons and spoilers is available). Aileron trim is not affected. Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***

19	PCU	PCU Internal leak (between both actuator chambers)	Normal control of the ailerons and spoilers systems will be maintained from both aileron control wheels. Indication: No cockpit light indication (latent failure)	Normal control of the ailerons and spoilers systems will be maintained from both aileron control wheels. Indication: No cockpit light indication (latent failure)	Does not match with failure scenario ***(Closed)***
20	PCU	PCU Jammed actuator piston at the neutral position.	Same effect as number 5.	Same effect as number 5.	
21	PCU	PCU Jammed actuator piston at a position offset from the neutral position.	Same effect as number 5.	Same effect as number 5.	
22	Aileron Spring Cartridge	Broken	Ailerons systems will not be affected. The spoilers will receive the mechanical input from the Captain aileron control wheel only after 12 degrees of wheel rotation through the transfer mechanism on the R.H. side. Forces required to drive the spoilers control mechanism will be added to the forces on the Captain control wheel The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional	Ailerons systems will not be affected. The spoilers will receive the mechanical input from the F/O aileron control wheel only after 12 degrees of wheel rotation through the transfer mechanism on the R.H. side. Forces required to drive the spoilers control mechanism will be added to the forces on the F/O control wheel The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional	Does not match with failure scenario ***(Closed)***

			Indication: No cockpit light indication (latent failure)	Indication: No cockpit light indication (latent failure)	
23	Aileron Spring Cartridge	Frozen (acting as a rigid rod)	Ailerons and spoilers systems will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: No cockpit light indication (latent failure)	Ailerons and spoilers systems will not be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: No cockpit light indication (latent failure)	Does not match with failure scenario ***(Closed)***
24	Spoiler input rod	Broken	Captain will be able to drive the ailerons in both directions at normal operating forces. All flight spoilers will be retracted The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: No cockpit light indication	F/O will be able to drive the ailerons in both directions at normal operating forces. All flight spoilers will be retracted The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still be functional Indication: No cockpit light indication	Does not match with failure scenario (***Closed)***
25	Spoiler input rod	Spoiler input rod jammed	Refer to cases No. 9,10	Refer to cases No. 9,10	Does not match with failure scenario ***(Closed)***
26	Spoiler control quadrant	Spoiler control quadrant jammed	Refer to cases No. 9,10	Refer to cases No. 9,10	Does not match with failure scenario ***(Closed)***
27	One spoiler control	Broken	Captain will be able to drive the ailerons in	F/O will be able to drive the ailerons in	Does not match with

	cable (F/O cable AA, AB)		both directions Captain will be able to drive the spoilers in both directions (through the aileron spring cartridge) F/O aileron wheel will follow Captain aileron wheel F/O aileron wheel will simultaneously follow the Captain aileron wheel The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still operate normally. This failure will only be evident in the case of jamming of the Captain aileron input side. In this case, the F/O will be able to control the spoilers in only one direction Indication: No cockpit light indication (latent failure)	both directions F/O will be able to drive the spoilers in both directions (through the captain aileron control wheel and the aileron spring cartridge) Captain aileron wheel will simultaneously follow the F/O aileron wheel The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Aileron trim will still operate normally. This failure will only be evident in the case of jamming of the Captain aileron input side. In this case, the F/O will be able to control the spoilers in only one direction Indication: No cockpit light indication (latent failure)	failure scenario ***(Closed)***
28	One spoiler control cable (F/O cable AA, AB)	Jammed	Refer to cases No. 9,10	Refer to cases No. 9,10	
29	Trim and centering mechanism	Aileron trim electric arming switch contact is stuck closed in	Ailerons and spoilers operation will not be affected. Aileron trim will still be functional normally in both directions. The ailerons will not be biased in any	Ailerons and spoilers operation will not be affected. Aileron trim will still be functional normally in both directions. The ailerons will not be biased in any	Does not match with failure scenario ***Closed***

		one direction	direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	
30	Trim and centering mechanism	Aileron trim electric direction control switch contact is stuck closed in one direction	Ailerons and spoilers operation will not be affected. Aileron trim will only move in one direction regardless of the trim command direction. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	Ailerons and spoilers operation from the F/O side will not be affected. Aileron trim will only move in one direction regardless of the trim command direction. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***
31	Trim and centering mechanism	Motor Failure, jammed at the center (neutral) position	Aileron trim will be lost Captain will be able to normally drive both the ailerons and the spoilers in both directions. With the Captain control wheel released, the wheel will return to neutral position. Indication: No cockpit light indication	Aileron trim will be lost F/O will be able to normally drive both the ailerons and the spoilers in both directions. With the F/O control wheel released, the wheel will return to neutral position. Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***
32	Trim and centering mechanism	Motor Failure, jammed offset from the center (neutral) position	Aileron trim will be lost The aileron wheel will be biased to a new trim position (function of the length of the trim actuator). Accordingly, the ailerons and spoilers will be deflected following the wheel	Aileron trim will be lost The aileron wheel will be biased to a new trim position (function of the length of the trim actuator). Accordingly, the ailerons and spoilers will be deflected following the wheel	(To be considered) Simulation has been done by Boeing. Refer to Chapter 2 Analysis

			new trim condition (the maximum authority of the aileron trim is 15 degree of aileron travel up or down). The captain will be able to drive both the ailerons and the spoilers in both directions from this new trim position. The forces on the control wheel will be function of the trim and centering mechanism force characteristics (refer to figure xx). When the Captain releases the control wheel, the wheel will return to the new trim position (offset of the neutral position) Indication: No cockpit light indication	new trim condition (the maximum authority of the aileron trim is 15 degree of aileron travel up or down). The F/O will be able to drive both the ailerons and the spoilers in both directions from this new trim position. The forces on the control wheel will be function of the trim and centering mechanism force characteristics (refer to figure xx). When the F/O releases the control wheel, the wheel will return to the new trim position (offset of the neutral position) Indication: No cockpit light indication	
33	Trim and centering mechanism	Broken centering springs	Aileron trim will be lost. Centering and feel actions will be lost. Captain will be able to drive both the ailerons and the spoilers in both directions Indication: No cockpit light indication	Aileron trim will be lost. Centering and feel actions will be lost. F/O will be able to drive both the ailerons and the spoilers in both directions Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***
34	Trim and centering mechanism	Broken centering cam	Depending on the location of the break and shape of the remaining section of the cam, this fault may result in an unrestrained or jammed centering mechanism. If unrestrained, see 33 above. If jammed, see item 5.	Depending on the location of the break and shape of the remaining section of the cam, this fault may result in an unrestrained or jammed centering mechanism. If unrestrained, see 33 above. If jammed, see item	(Does not match with failure scenario ***(Closed)***

			Indication: No cockpit light indication	5. Indication: No cockpit light indication	
35	Ailerons bus cable ABSA, ABSB	Broken Cable	The aileron surface connected to the affected cable will be driven in one direction only Captain will be able to control the spoilers normally F/O aileron control wheel will follow the Captain aileron control wheel. The ailerons wheels will not be biased in any direction by the aileron control system with the control wheel at no load condition. During flight, the position of the affected aileron will depend on whether the failure in the up or down cable. Aerodynamic loads tend to move the ailerons upwards. Indication: No cockpit light indication	The aileron surface connected to the affected cable will be driven in one direction only F/O will be able to control the spoilers normally Captain aileron control wheel will follow the F/O aileron control wheel. The ailerons wheels will not be biased in any direction by the aileron control system with the control wheel at no load condition. During flight, the position of the affected aileron will depend on whether the failure in the up or down cable. Aerodynamic loads tend to move the ailerons upwards. Indication: No cockpit light indication	Does not match with failure scenario based on FDR data ***(Closed)***
36	Ailerons bus cable ABSA, ABSB	Jammed Cable at center (neutral) position.	The aileron surface connected to the affected cable will jam at the neutral position. When either control wheel is rotated, the PCU connected to the unaffected bus cable will apply force on the relevant output drum. This drum will be resisted by the other drum connected to the jammed bus cable. Consequently, the shear rivets on	The aileron surface connected to the affected cable will jam at the neutral position. When either control wheel is rotated, the PCU connected to the unaffected bus cable will apply force on the relevant output drum. This drum will be resisted by the other drum connected to the jammed bus cable. Consequently,	Does not match with failure scenario ***(Closed)***

			the aileron drums will break. After breaking the shear rivets, the Captain will be able to drive the unaffected aileron surface and spoilers normally. Both wheels will move normally. Aileron trim is not affected except that the jammed aileron will not respond. Indication: No cockpit light indication	the shear rivets on the aileron drums will break. After breaking the shear rivets, the F/O will be able to drive the unaffected aileron surface and spoilers normally. Both wheels will move normally. Aileron trim is not affected except that the jammed aileron will not respond. Indication: No cockpit light indication	
37	Aileron bus drum	Jammed Aileron bus drum at the center (neutral) position	Similar to case 36	Similar to case 36	Does not match with failure scenario ***(Closed)***
38	Ailerons bus cable ABSA, ABSB	Jammed Cable at a position offset from the center (neutral) position.	Similar to case 36 except that: The aileron surface connected to the affected cable will jam at a position offset from the neutral position.	Similar to case 36 except that: The aileron surface connected to the affected cable will jam at a position offset from the neutral position.	Does not match with failure scenario ***(Closed)***
39	Aileron bus drum	Jammed Aileron bus drum at a position offset from the neutral position	Similar to case 38	Similar to case 38	Does not match with failure scenario ***(Closed)***
40	Aileron bus drum	Broken lug or fork	Ailerons and spoilers operation will not be affected (as long as A and B hydraulic systems are available).	Ailerons and spoilers operation will not be affected (as long as A and B hydraulic systems are available).	Does not match with failure scenario ***(Closed)***

			Aileron trim will be functioning normally The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	Aileron trim will be functioning normally The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	
41	Aileron wing Quadrant	Aileron wing Quadrant jammed	Similar to cases 36 and 38	Similar to cases 36 and 38	Does not match with failure scenario ***(Closed)***
42	Cable tension spring	Cable tension spring broken (at one side)	Broken spring may cause slackening of the ailerons bus system cables (ABSA and ABSB). This may affect the connection between the ailerons bus drums and the ailerons wing quadrants which may cause some delays in the ailerons movement. No other systems will be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	Broken spring may cause slackening of the ailerons bus system cables (ABSA and ABSB). This may affect the connection between the ailerons bus drums and the ailerons wing quadrants which may cause some delays in the ailerons movement. No other systems will be affected. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	Does not match with failure scenario ***(Closed)***
43	Aileron balance panel	Damaged Aileron balance panel	Captain will still be able to drive the ailerons and spoilers normally without additional forces (as long as at least one of the A or B hydraulic	F/O will still be able to drive the ailerons and spoilers normally without additional forces (as long as at least one of the A or B hydraulic systems	Does not match with failure scenario ***(Closed)***

			systems is available) Aileron trim will not be affected. Ailerons control will be less effective and heavier in the manual reversion mode The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	is available) Aileron trim will not be affected. Ailerons control will be less effective and heavier in the manual reversion mode The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	
44	Aileron balance tab	Damaged aileron control tab	Captain will still be able to drive the ailerons and spoilers normally without additional forces (as long as at least one of the A or B hydraulic systems is available) Aileron trim will not be affected. Ailerons control will be less effective and heavier in the manual reversion mode The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	F/O will still be able to drive the ailerons and spoilers normally without additional forces (as long as at least one of the A or B hydraulic systems is available) Aileron trim will not be affected. Ailerons control will be less effective and heavier in the manual reversion mode The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (may be a latent failure)	Does not match with failure scenario ***(Closed)***
45	Shear rivets at the attach point between the spring cartridge and the control	Shear rivets at the attach point between the spring cartridge and the	The connection between the ailerons bus drums and the spoiler quadrant will be lost. Ailerons control will not be affected using either ailerons control	The connection between the ailerons bus drums and the spoiler quadrant will be lost. Ailerons control will not be affected using either ailerons control	Does not match with failure scenario ***(Closed)***

	quadrant shaft input crank	control quadrant shaft input crank are sheared	wheel. The spoilers will receive mechanical input from the Captain aileron wheel only after about 12 degrees of wheel rotation causing a delay in the flight spoilers operation The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	wheel. The spoilers will receive mechanical input from the Captain aileron wheel only after about 12 degrees of wheel rotation causing a delay in the flight spoilers operation The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	
46	Aileron cam (spoiler mixer)	Aileron cam (spoiler mixer) jammed	Similar to cases 9 and 10	Similar to cases 9 and 10	Does not match with failure scenario ***(Closed)***
47	Left or right spoiler output quadrant	Left or right spoiler output quadrant jammed	The flight spoilers on the both sides will jam at positions dependent on the jammed quadrant position. Normal aileron control will be available up to 12 degrees each side of the jam. Beyond 12 degrees, additional force is necessary to overcome the transfer mechanism.	The flight spoilers on the both sides will jam at positions dependent on the jammed quadrant position. Normal aileron control will be available up to 12 degrees each side of the jam. Beyond 12 degrees, additional force is necessary to overcome the transfer mechanism.	Does not match with failure scenario ***(Closed)***
48	Speed brake input quadrant	Speed brake input quadrant jammed (at the speed brake retracted position)	Only the speed brake will be lost. Ailerons and flight spoilers operation will not be affected	Only the speed brake will be lost. Ailerons and flight spoilers operation will not be affected	Does not match with failure scenario ***(Closed)***

Table 2- Hypothetical double failures scenarios (Ailerons/ Spoilers Systems)

Ser.	Failed Component	Type of Failure	Input from Captain	Input from F/O	
1	Both hydraulic systems A and B	Total Hydraulic Failure	Captain will maintain ailerons control manually through the aileron cables on the left side, PCU stops and the ailerons bus cables. Control forces are minimized by aileron balance tabs and balance panels. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Ailerons movements may be affected by external disturbances and aircraft maneuvers. The Captain has to overcome the aileron loads and the centering spring All the spoilers will be lost and will stay at the faired position. Aileron trim will be lost Indication: FLT Control A and B LOW PRESSURE lights will illuminate, systems A and B low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant pumps LOW PRESSURE lights will illuminate, hydraulic fault light on right light shield will illuminate.	F/O will maintain ailerons control manually through the override mechanism on the right side, aileron cables on the left side, PCU stops and the ailerons bus cables. Control forces are minimized by aileron balance tabs and balance panels. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Ailerons movements may be affected by external disturbances and aircraft maneuvers. The F/O has to overcome the aileron loads and the centering spring All the spoilers will be lost and will stay at the faired position. . Aileron trim will be lost. Indication: FLT Control A and B LOW PRESSURE lights will illuminate, systems A and B low press reading will be visible on the Secondary Engine and Hydraulic Display, relevant pumps LOW PRESSURE lights will illuminate, hydraulic	Does not match with failure scenario ***(Closed)***

				fault light on right light shield will illuminate.	
2	Aileron trim switches	Both trim switches are stuck closed in the same direction	The aileron trim actuator will reach its hard over position driving the ailerons to 15 degrees (maximum trim authority). Both aileron wheels will be driven away from the neutral position. The ailerons and flight spoilers will always follow the aileron wheel. The new position for the wheel will be about 65 degrees. The force-wheels relation will change (refer to Force vs wheel chart) Whenever the aileron wheels are released, the wheels will move to the hardover position (65 degree). The ailerons wheels will always simultaneously follow each others. Indication: No cockpit light indication	The aileron trim actuator will reach its hard over position driving the ailerons to 15 degrees (maximum trim authority). Both aileron wheels will be driven away from the neutral position. The ailerons and flight spoilers will always follow the aileron wheel. The new position for the wheel will be about 65 degrees. The force-wheels relation will change (refer to Force vs wheel chart) Whenever the aileron wheels are released, the wheels will move to the hardover position (65 degree). The ailerons wheels will always simultaneously follow each others. Indication: No cockpit light indication	Refer to Chapter 2 Analysis
3	One spoiler control cable (F/O cable AA, AB), Captain aileron input side	Spoilers control cable broken + jamming of the Captain aileron input side.	Captain will not be able to control neither the ailerons nor the flight spoilers Indication: No cockpit light indication (latent failure)	The F/O will be able to control the spoilers in only one direction. No control on aileron system Indication: No cockpit light indication (latent failure)	Does not match with failure scenario ***(Closed)***
4	Trim and centering mechanism	Broken centering springs	Aileron trim will be lost. Centering and feel actions will be lost. Captain will be able to drive both the ailerons and the spoilers in both directions Indication:	Aileron trim will be lost. Centering and feel actions will be lost. F/O will be able to drive both the ailerons and the spoilers in both directions Indication:	Does not match with failure scenario ***(Closed)***

			No cockpit light indication	No cockpit light indication	
5	Aileron bus drum, Hydraulic system	Broken lug or fork + one hydraulic system is lost (A or B)	Ailerons and spoilers operation will not be affected as long as A and B hydraulic systems are available. Aileron trim will be functioning normally The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. In case of failure of A or B systems, one aileron surface will be controlled by manual reversion, resulting in increased forces at the wheel. Spoilers 3, 6 will be lost in case of A system failure. Outboard Flight Spoilers 2, 7 will be lost in case of B system failure. Indication: No cockpit light indication	Ailerons and spoilers operation will not be affected (as long as A and B hydraulic systems are available). Aileron trim will be functioning normally The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. In case of failure of A or B systems, one aileron surface will be controlled by manual reversion, resulting in increased forces at the wheel. Spoilers 3, 6 will be lost in case of A system failure. Outboard Flight Spoilers 2, 7 will be lost in case of B system failure Indication: No cockpit light indication	Does not match with failure scenario ***(Closed)***

Table 3- Hypothetical failures scenarios (Autopilot Actuator)

Ser.	Failed Component	Type of Failure	Input from Captain	Input from F/O	
1	Arm Solenoid	Arm Solenoid Stuck Open	With the arm solenoid open, the autopilot mod piston can move in response to FCC commands. When disengaged, the FCC commands the transfer valve as to center the A/P piston. However, as the detent solenoid is not open, the A/P piston is not coupled to the ailerons and the A/P actuator cannot command aileron motion. Captain will be able to control the ailerons and spoilers normally with autopilot disengaged. The autopilot can also be engaged normally. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	With the arm solenoid open, the autopilot mod piston can move in response to FCC commands. When disengaged, the FCC commands the transfer valve as to center the A/P piston. However, as the detent solenoid is not open, the A/P piston is not coupled to the ailerons and the A/P actuator cannot command aileron motion. F/O will be able to control the ailerons and spoilers normally with autopilot disengaged. The autopilot can also be engaged normally. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication (latent failure)	Does not match with failure scenario ***(Closed)***
2	Detent Solenoid	Detent Solenoid Stuck Open	The arm and detent solenoids are in series. With the autopilot is not engaged, the arm solenoid will be closed, no hydraulic fluid will be available to allow the detent pistons to couple the	The arm and detent solenoids are in series. With the autopilot is not engaged, the arm solenoid will be closed, no hydraulic fluid will be available to allow the detent pistons to couple the	Does not match with failure scenario ***(Closed)***

			A/P piston to the ailerons. The A/P actuator cannot command aileron motion. If this fault exists when the autopilot is trying to engage, the FCC would detect hydraulic pressure before it is commanded and would disconnect the A/P within 182 ms.[2] Captain will be able to control the ailerons and spoilers normally with autopilot disengaged. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	A/P piston to the ailerons. The A/P actuator cannot command aileron motion. If this fault exists when the autopilot is trying to engage, the FCC would detect hydraulic pressure before it is commanded and would disconnect the A/P within 182 ms. F/O will be able to control the ailerons and spoilers normally with autopilot disengaged. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	
3	Arm and Detent Solenoids	Arm and Detent Solenoids Stuck Open	This is the normal condition when the autopilot is engaged. If the autopilot is not engaged, the FCC commands the transfer valve to hold the autopilot actuator in the neutral (ailerons faired) position. Because both the solenoids are stuck open, the transfer valve spool moves the A/P piston in response to commands from the FCC and the detent	This is the normal condition when the autopilot is engaged. If the autopilot is not engaged, the FCC commands the transfer valve to hold the autopilot actuator in the neutral (ailerons faired) position. Because both the solenoids are stuck open, the transfer valve spool moves the A/P piston in response to commands from the FCC and the detent	Does not match with failure scenario ***(Closed)***

[2] This information is based on the correction made in Boeing presentation (Scenario 12 ver 2.ppt). Boeing and Honeywell are requested to forward official document presenting this information.
[3] This figure was presented by Boeing during Cairo meeting February 1st, 2005

			pistons are pressurized to couple the actuator to the ailerons. Normal autopilot actuator breakout is still available to override the autopilot actuator malfunction. Without pilot intervention, the net result would be the same as letting go of the wheel and letting it center. Captain will be able to control the ailerons and spoilers with autopilot disengaged, but with an additional force of 17 lbs[3] to overcome detent piston pressure and override the autopilot. The autopilot can not be engaged. Detent pressure switch will sense hydraulic pressure; therefore, the pre- engagement logic will not be valid preventing engagement of autopilot. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	pistons are pressurized to couple the actuator to the ailerons. Normal autopilot actuator breakout is still available to override the autopilot actuator malfunction. Without pilot intervention, the net result would be the same as letting go of the wheel and letting it center. Captain will be able to control the ailerons and spoilers with autopilot disengaged, but with an additional force of 17 lbs to overcome detent piston pressure and override the autopilot. The autopilot can not be engaged. Detent pressure switch will sense hydraulic pressure; therefore, the pre- engagement logic will not be valid preventing engagement of autopilot. The ailerons will not be biased in any direction by the aileron control system with the control wheel at no load condition. Indication: No cockpit light indication	
4	Both Solenoids and the Transfer Valve	Both Solenoids Stuck Open with Transfer Valve Jammed offset of	This triple fault will result in an A/P actuator hardover. The autopilot can not be engaged. Detent pressure switch will sense hydraulic pressure before	This triple fault will result in an A/P actuator hardover. The autopilot can not be engaged. Detent pressure switch will sense hydraulic pressure before	Simulation has been done by Boeing. Refer to Chapter 2 Analysis

		the neutral position	engagement; therefore, the pre-engagement logic will not be valid preventing engagement of autopilot. With autopilot disengaged, both aileron wheels will be driven away of the neutral position and will be positioned at about 60 degrees (wheel position) Refer to figure xxx, forces versus wheels position) The ailerons and flight spoilers will follow movement of the ailerons control wheels. The Captain will be able to control the ailerons and flight spoilers with an additional force of 17 lbs to overcome detent piston pressure and override the autopilot. Whenever the control wheels are released, the control wheel will return to the relevant autopilot actuator hardover position (60 degrees wheel position), resulting in an aileron deflection of about ± 13 degrees and spoilers deflection. Note: Depressurizing the relevant hydraulic system powering the faulty autopilot actuator will eliminate the fault.	engagement; therefore, the pre-engagement logic will not be valid preventing engagement of autopilot. With autopilot disengaged, both aileron wheels will be driven away of the neutral position and will be positioned at about 60 degrees (wheel position) Refer to figure xxx, forces versus wheels position) The ailerons and flight spoilers will follow movement of the ailerons control wheels. The Captain will be able to control the ailerons and flight spoilers with an additional force of 17 lbs to overcome detent piston pressure and override the autopilot. Whenever the control wheels are released, the control wheel will return to the relevant autopilot actuator hardover position (60 degrees wheel position), resulting in an aileron deflection of about ± 13 degrees and spoilers deflection. Note: Depressurizing the relevant hydraulic system powering the faulty autopilot actuator will eliminate	

			Indication: No cockpit light indication	the fault. Indication: No cockpit light indication	
5	Both Solenoids, Transfer Valve and Pressure Regulator	Both Solenoids Stuck Open, Transfer Valve and Pressure Regulator Jammed	This quadruple fault will result in an A/P actuator hardover. Because of the pressure regulator jam, the relief valve operates and wheel forces to overcome the autopilot hardover increase from 17 lbs (normal) to approximately 20 lbs. Other than that, this failure will be similar to failure case 4	This quadruple fault will result in an A/P actuator hardover. Because of the pressure regulator jam, the relief valve operates and wheel forces to overcome the autopilot hardover increase from 17 lbs (normal) to approximately 20 lbs. Other than that, this failure will be similar to failure case 4	Simulation has been done by Boeing. Refer to Chapter 2 Analysis
6	Both Solenoids, Transfer Valve and Relief Valve	Both Solenoids Stuck Open, Transfer Valve and Relief Valve Jammed	This condition is similar to condition 4 This quadruple fault will result in an A/P actuator hardover. Although the relief valve is jammed (stuck to pressure regulator slide), the primary pressure regulator still operates normally and wheel force to overcome the autopilot is approximately 17 lbs.	This condition is similar to condition 4 This quadruple fault will result in an A/P actuator hardover. Although the relief valve is jammed (stuck to pressure regulator slide), the primary pressure regulator still operates normally and wheel force to overcome the autopilot is approximately 17 lbs.	Simulation has been done by Boeing. Refer to Chapter 2 Analysis
7	Both Solenoids, Transfer Valve, Pressure Regulator, and Relief Valve	Both Solenoids Stuck Open, Transfer Valve Pressure Regulator,	This quintuple fault will result in an A/P actuator hardover. With both the pressure regulator and relief valve jammed, the	This quintuple fault will result in an A/P actuator hardover. With both the pressure regulator and relief valve jammed, the	Simulation has been done by Boeing. Refer to Chapter 2 Analysis

		and Relief Valve Jammed	wheel force required to overcome the autopilot is approximately 80 lbs. Other than that, this failure will be similar to failure case 4	wheel force required to overcome the autopilot is approximately 80 lbs. Other than that, this failure will be similar to failure case 4	

Appendix 2-2 Studies of other airplane incidents relevant to autoflight systems

Two cases of malfunctions related to Boeing 737-500 autopilot system were reported by one operator as follows:

I- CASE of "AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT"

1- BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/8/2004 2:25:33 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
One Operator reports that during descent with A/P A engages, VS mode selected and 1500 FPM selected on MCP panel airplane started a descent with a rate of 3000 FPM. Crew reported that this occurred two times. Crew reported that A/P operated normal.

Maintenance reported the following AFDS Bite results:

Possible Causes
Stab Trim M255
Elevator Pos. Sensor
Stab. Pos. Sen-1

Attached for review is DFDR data for the flight which started at 2000 GMT and ended at 2110 GMT.

ACTION:

The operator requests that Boeing review the submitted DFDR data and advise findings.

Attachment: autopilot.pdf Date 11/8/2004 1:38:59 AM

Commercial Aviation Services
The Boeing Company

11/8/2004 2:25:33 AM PST

2. BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/21/2004 2:55:20 AM PST

[MESSAGE NUMBER: 1-STLI4]
FROM: THE BOEING COMPANY

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /A/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. Boeing would be interested in knowing the altitude that was selected during the event and at what altitude the capture maneuver was initiated. Any available FDR data may be helpful in reviewing this event.

Regarding the A/P bite faults, Boeing would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an operator mechanic while in the flight deck of the airplane.

Please advise if the operator can support further troubleshooting using a cell phone in the flight deck where the FCC BITE can be performed via telecon with Boeing. If affirmative, please provide a time and phone number that Boeing can contact.

As reported previously, the operator has performed adjustments of the Ref /D/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Datum airplane is currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /D/ rods.

ACTION:

Please review and advise if Boeing concurs with the operator on replacement of the Ref /D/ rods.

Commercial Aviation Services
The Boeing Company

3- BOEING REPLY, EXCESSIVE RATE OF DESCENT
23-Nov-2004 11:42:51 AM PST

[SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /A/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised we would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an the operator mechanic while in the flight deck of the airplane.

As reported previously, the operator has performed adjustments of the Ref /D/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Datum airplane is currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /D/ rods.

ACTION:

Please review and advise if Boeing concurs with the operator on replacement of the Ref /D/ rods.

RESPONSE:

Last night, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

Commercial Aviation Services
The Boeing Company

4- BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/30/2004 4:07:08 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /C/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised they would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an operator mechanic while in the flight deck of the airplane. As reported previously, the operator has performed adjustments of the Ref /E/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Ref /B/ advised that datum airplane was currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /F/ rods.

On 22-Nov-2004, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Ref /A/ advised that based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

The operator replaced and adjusted the Ref /F/ rods and released the airplane for service. On 26-Nov-2004 the crew reported that, with A/P "A" engaged and V/S of 2000 FPM selected, aircraft descent was 4,000 FPM. See attached log sheet for details. On 28-Nov-2004, crew reported that with A/P "A" engaged MCP ALT 33,000, FMA- ALT ACQ the airplane started a descent of more than 2000 FPM. Please see attached log sheet for details. Aircraft is currently operating using A/P "B" only.

Attached for review is DFDR data for the 26-Nov event flight leg. As reported above, the reported excessive descent rate was during descent.

The operator is requesting that Boeing review the data and report findings. The operator management has also requested on-site technical assist.

ACTION:

1. Please review the attached DFDR data and report findings.

2. Please advise if Boeing can provide on-site technical assist.

A response by 01-Dec is requested.

Commercial Aviation Services

The Boeing Company

11/30/2004 4:07:08 AM PST

5- BOEING REPLY, EXCESSIVE RATE OF DESCENT
01-Dec-2004 01:52:43 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /C/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised they would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an the operator mechanic while in the flight deck of the airplane. As reported previously, the operator has performed adjustments of the Ref /F/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Ref /B/ advised that datum airplane was currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /F/ rods.

On 22-Nov-2004, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Ref /A/ advised that based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

The operator replaced and adjusted the Ref /F/ rods and released the airplane for service. On 26-Nov-2004 the crew reported that, with A/P "A" engaged and V/S of 2000 FPM selected, aircraft descent was 4,000 FPM. See attached log sheet for details. On 28-Nov-2004, crew reported that with A/P "A" engaged MCP ALT 33,000, FMA- ALT ACQ the airplane started a descent of more than 2000 FPM. Please see attached log sheet for details. Aircraft is currently operating using A/P "B" only.

Attached for review is DFDR data. As reported above, the reported excessive descent rate was during descent into SSH.

The operator is requesting that Boeing review the data and report findings. The operator management has also requested on-site technical assist.

ACTION:

1. Please review the attached DFDR data and report findings.

2. Please advise if Boeing can provide on-site technical assist.

Reply:

Boeing has reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing would recommend the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Commercial Aviation Services
The Boeing Company

01-Dec-2004 01:52:43 PM PST

6- BOEING REPLY, EXCESSIVE RATE OF DESCENT
03-Dec-2004 03:38:20 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:

This is to advise that Boeing has reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review.

Commercial Aviation Services
The Boeing Company

03-Dec-2004 03:38:20 PM PST

7- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
12/6/2004 5:56:58 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to Ref /D/, Ref /C/ advised that Boeing had reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing recommended the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Ref /B/ provided results of the above recommended tests.

Ref /A/ advised that Boeing had reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review. The operator has reviewed the Ref /A/ and /C/ responses and is requesting clarification regarding the intermittent trim command output from FCC A. As reported above, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. It was also verified that there were other times in the data where A did command trim in both directions, so FCC A was (is) capable of trim.

The operator is requesting further Boeing recommendations and on-site tech assist.

ACTION:

1. Based on the above data is replacement of the FCC A horizontal position sensor and sensor wiring check recommended?

2. Based on the above data, is an intermittent circuit between FCC A D1671B, pin 42, wire 102-20 to splice SP3677 a possible cause of the intermittent trim UP command?

3. Please advise any additional wiring checks to be performed.

Commercial Aviation Services
The Boeing Company

12/6/2004 5:56:58 AM PST

8- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
09-Nov-2004 03:42:22 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
The operator reports that, during descent with A/P A engages, VS mode selected and 1500 FPM selected on MCP panel airplane started a descent with a rate of 3000 FPM. Crew reported that this occurred two times. Crew reported that A/P operated normal.

Maintenance reported the following AFDS Bite results:

Possible Causes
Stab Trim M255
Elevator Pos. Sensor
Stab. Pos. Sen-1

Attached for review is DFDR data for the flight.

ACTION:

The operator requests that Boeing review the submitted DFDR data and advise findings.

Reply,

Boeing has reviewed the FDR data and we do not identify any unusual autopilot operation noted in the reviewed data. The selected V/S is not recorded and therefore it is difficult to determine how well the autopilot is tracking vertical speed. We produced a derivative of the airplane altitude to determine where in the flight the vertical speed was 3000 feet per minute or greater. The resulting vertical speed data plot did not confirm any flight segment that exhibited a vertical speed of 3000 feet per minute or greater. As an added note, if the winds change with altitude, the airplane vertical speed will be upset in the short term from that selected.

Commercial Aviation Services
The Boeing Company

09-Nov-2004 03:42:22 PM PST

9- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
07-Dec-2004 04:19:07 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to Ref /D/, Ref /C/ advised that Boeing had reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing recommended the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Ref /B/ provided results of the above recommended tests.

Ref /A/ advised that Boeing had reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review. the operator has reviewed the Ref /A/ and /C/ responses and is requesting clarification regarding the intermittent trim command output from FCC A. As reported above, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. It was also verified that there were other times in the data where A did command trim in both directions, so FCC A was (is) capable of trim.

The operator is requesting further Boeing recommendations and on-site tech assist.

ACTION:

1. Based on the above data is replacement of the FCC A horizontal position sensor and sensor wiring check recommended?

2. Based on the above data, is an intermittent circuit between FCC A D1671B, pin 42, wire 102-20 to splice SP3677 a possible cause of the intermittent trim UP command?

3. Please advise any additional wiring checks to be performed.

Reply:

The stab position data is used in determining trim thresholds. We also agree that an open between FCC A D1671B pin 42 would result in the A channel FCC being unable to command a trim up. Therefore, replacement of the stab position sensor and sensor wire verification is recommended.

We understand that the airplane has returned to service and we have no further recommendations at this time.

Commercial Aviation Services
The Boeing Company

07-Dec-2004 04:19:07 PM PST

10- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
12/13/2004 6:06:11 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
Refs /A/ thru /E/ discuss subject events and troubleshooting accomplished by the operator and Boeing recommendations.

Pilot reported the following: "During descent to FL160, A/P "A" engaged, FMA displayed ALT ACQUIRE but airplane continued descent." Airplane returned with A/P "B" engaged and no faults were noted. Airplane has been operating using A/P "B".

The operator has provided the attached DFDR data for the event. Please note the altitude reported above may be 1,600 feet vs FL160.

The airplane is currently out of service for troubleshooting.

ACTION:

The operator requests that Boeing review the attached DFDR data and advise findings.

Commercial Aviation Services
The Boeing Company

12/13/2004 6:06:11 AM PST

11- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
13-Dec-2004 11:06:19 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
Refs /A/ thru /E/ discuss subject events and troubleshooting accomplished by the operator and Boeing recommendations.

Pilot reported the following: "During descent to FL160, A/P "A" engaged, FMA displayed ALT ACQUIRE but airplane continued descent." Airplane returned with A/P "B" engaged and no faults were noted. Airplane has been operating using A/P "B".

The operator has provided the attached DFDR data for the event. Please note the altitude reported above may be 1,600 feet vs FL160.

The airplane is currently out of service for troubleshooting.

ACTION:

the operator requests that Boeing review the attached DFDR data and advise findings.

RESPONSE:

For this event, it appears that when ALT ACQUIRE was engaged the elevator moved about 1 degree to slow the rate of descent and then remained flat at that value for the 10 seconds it was in the mode. It appears there was not enough elevator authority on the A side to finish pitching the airplane up, and it continued to slowly pitch down until the autopilot was disconnected.

Also during the acquire, the autopilot was not trimming the stabilizer. Since the flaps were at 1, the autopilot trims based on elevator position. Therefore, the autopilot probably could not move the quadrant far enough. Based on this and the previous event, it would appear that the A actuator does not have the required authority, for whatever reason.

Commercial Aviation Services
The Boeing Company

II- CASE of AUTOPILOT OVERBANK

1- Case of Overbank Follow up:

Model: 737 - 500

Pilot Report:

During Departure with LNAV engaged, when selecting A/P "B", A/P "B" engaged then disengaged. After satisfying F/D again A/P selected then autopilot gives more than 35 deg. bank angle and increasing. A/P disconnected again followed by F/D Pitch bar out of view. F/D switches recycled off-on.

After Flap retraction and with aircraft was leveled A/P selected again operates normally (A & B)

Maintenance Action:

- Autoflight system checked on ground from MCDU according to M.M. found operating normal.
- Last flight faults checked, found no faults recorded.
- Both IRS checked found OK
- Flight data recorder removed for read out and aircraft released for flight.
- Snag not repeated on the next flights but FDR read out for the subject flight shows that autopilot exceeds bank angle limitation.
- A/P "B" was deactivated and considered A/P "B" D. Defect according to MEL.

N.B
The airplane has a history in flight control problems, Boeing have the full details.
(Subject Flight FDR raw data available if needed)

2- BOEING COMPANY REPLY
3/27/2005 4:30:18 AM PST

Please do not reply. This message is the acknowledgement of your request.

Your Service Request has been received by The Boeing Company. Your request will be reviewed and a response provided in accordance with your request. Thank you for your inquiry.

SUBJECT: Autopilot Overbank /
DESCRIPTION:
T he flight crew reported the following:

During departure with LNAV engaged, AP "B" selected, the AP "B" engaged then disengaged. After satisfying F/D, again AP selected. At UTC 20:14 the autopilot gave more than 35 degree bank angle and increased.   A/P disconnected followed by F/D pitch bar out of view, F/D switches recycled. Flap retraction and leveled, AP selected and operation normal.

Maintenance Action:
the operator maintenance checked on ground Autopilot system from MCDU and per MM no findings. Both IRS checked no finding. FDR removed for analysis and plane released back on flight line. Snag didn't reappear on the next flight. According to FDR the subject airplane had an autopilot exceeds bank angle limitations.
The operator deactivated the AP "B" and considered the AP "B" defected according to MEL.
The FDR raw data is available for Boeing review if required.

Action:
The airplane has a history of heavy flight control per Ref /A/ SR.
The subject Airplane is currently AOG for troubleshooting.
Please review the above information and advise the operator with any recommended troubleshooting.

Commercial Aviation Services
The Boeing Company

3/27/2005 4:30:18 AM PST

3- BOEING COMPANY REPLY
28-Mar-2005 04:47:03 PM PST

REFERENCES:
Ref /A/ SR 1-57258797

SUBJECT: Autopilot Overbank /
DESCRIPTION:
The flight crew reported the following:

During departure with LNAV engaged, AP "B" selected, the AP "B" engaged then disengaged. After satisfying F/D, again AP selected. At UTC 20:14 the autopilot gave more than 35 degree bank angle and increased. A/P disconnected followed by F/D pitch bar out of view, F/D switches recycled. Flap retraction and leveled, AP selected and operation normal.

Maintenance Action:
the operator maintenance checked on ground Autopilot system from MCDU and per MM no findings. Both IRS checked no finding. FDR removed for analysis and plane released back on flight line. Snag didn't reappear on the next flight. According to FDR the subject airplane had an autopilot exceeds bank angle limitations.

The operator deactivated the AP "B" and considered the AP "B" defected according to MEL.
The FDR raw data is available for Boeing review if required.

ACTION:

The airplane has a history of heavy flight control per Ref /A/ SR.

The subject Airplane is currently AOG for troubleshooting.
Please review the above information and advise the operator with any recommended troubleshooting.

As a follow-up, the operator attached the FDR data to Message Number: 1-1A4J4N.

RESPONSE:

We have analyzed the flight data recorder data provided by the operator, and are providing that analysis, followed by troubleshooting suggestions. The figures referred to in the analysis are provided as attachments to this response.

FDR Analysis

Analysis of the FDR data indicate that the overbank resulted when the pilot released the wheel, possibly to engage the autopilot, while the airplane had been trimmed with approximately 1.5 degrees of nose-left rudder pedal. Figure 1 presents the lateral and directional data for the event; for reference, the longitudinal parameters during the event are provided in Figure 2, although they did not play a significant role in the overbank.

The airplane performed a flaps 5 takeoff, becoming airborne at time 546 according to the air/ground logic. The airplane climbed out at 160 KCAS and shortly after lift off initiated a left turn from heading 295 towards heading 170. The wind was out of heading 050, increasing to about 25 knots in the air - this would constitute a quartering right tailwind transitioning to a quartering left tailwind. Note that FDR wind data are not valid on the ground.

At liftoff, the control wheel was deflected to about 25 degree right, and held at that deflection to maintain wings level. As the left turn was initiated, wheel was relaxed back to neutral and then deflected slightly left. At time 570 the wheel was relaxed to neutral and the A/P "B" was engaged - at this time the airplane had zero control wheel displacement but was rolling left at about 2.5 deg/sec. After about 1 sec, the A/P "B" disengaged. The control wheel was then deflected to the right, again to about 25 degrees, and arrested the roll at 30 degrees of left bank. At time 592 the control wheel returned to neutral and the A/P "B" channel was engaged again. As the wheel returned to neutral, the airplane again began to roll left at about 2 deg/sec. At time 597 the A/P "B" disengaged a second time and the CWS ROLL discrete (not shown) briefly engaged for 1 frame. Control wheel was deflected to 40 degrees right, the bank angle returned to zero and then continued right to about 4 degrees, then wheel was relaxed back to about 20 degrees right to hold bank angle between 5-8 degrees right.

During the entire event, from liftoff to the CWS engage and the roll back to 5-8 degrees right, the airplane appears to have been in a small nose-left sideslip. Rudder pedal indicates about 1.5 degrees nose left, and rudder position indicates about 2.7 degrees nose left. Furthermore, lateral acceleration persisted throughout the event at about -.03 g's, another indication of small sideslip angle. A simulation of the event confirms that, for the airspeed, altitude, and airplane configuration, a rudder pedal input of 1.5 degrees would give about 2.7 degrees of rudder and would require about 26 degrees of right wheel to balance. As the airspeed increased (FDR time 605 and on) the rudder blew down, and the amount of wheel required to balance reduced to about 20 degrees.

Figure 3 shows the takeoff roll. At time 505, the engines began to spool up - prior to this, the rudder pedal and rudder position parameters are both very close to zero (neutral). Shortly afterwards, several large pedal and rudder deflections occurred, accompanied by changes in heading. This is not unusual at the beginning of a takeoff roll and generally indicates that the pilot was aligning the aircraft on the runway centerline. By time 530 the rudder pedal deflections had subsided, but the rudder pedal position remained approximately at 1-2 degrees nose-left. The reason for this is unknown, but the deflection of pedal is confirmed by the accompanying rudder deflection of approximately 2-3 degrees nose left.

Figure 4 shows the FDR data after the event. At time 690, the flaps had been retracted to UP, and the airplane was just completing a left turn to heading 170, with bank angle returning to neutral. At this time, the pedal remained deflected at 1.3 degrees nose left, the rudder position was 2.2 degrees nose left, and 20 degrees of right wheel were required to hold the wings level. At this airspeed (now 205 KCAS) the simulation again indicates that this is consistent. As airspeed began increasing toward 250 KCAS, the rudder pedal and rudder position slowly neutralized; this was likely the result of manual trim adjustments by the crew, as the rudder appears to return in steps similar to the trim rate (note the expanded scale on rudder pedal on Figure 4). During the descent, as airspeed increased, the data indicate that the rudder pedal and rudder position remained near neutral, further suggesting that the situation was corrected during the cruise.

Conclusion

The FDR data indicate that PT561 experienced an overbank during an attempted autopilot engage because the airplane was in a small nose-left sideslip as the result of rudder pedal being deflected to approximately 1.5 degrees nose left. The reasons for this are unknown and cannot be determined from the FDR data, but the trim likely arose either from crew trim inputs during the takeoff roll (possibly inadvertent) or from something sticking in the rudder feel and centering unit. The simulation confirms that the sideslip resulting from the pedal input would have required approximately 25 degrees of right control wheel deflection to maintain wings level flight, as indicated by the FDR data. During each attempt to engage the "B" autopilot, the wheel was released to neutral and the airplane rolled at between 2 and 2.5 deg/sec as a result of the sideslip-induced roll.

Past experience with lateral trim issues on 737's would indicate that flap rigging was not a factor, as the roll that can be produced by flap mis-rigging is not nearly large enough to require 25 degrees of control wheel. Small sideslip angles, on the other hand, can produce significant roll asymmetries.

From the data provided, the autopilot was working normally.

We suggest that the operator accomplish the following troubleshooting:

- Do a test of the rudder centering
  AMM 27-21-00 Task S 735-012-001

- Do a test of the rudder pedal forces
  AMM 27-21-00 Task S 735-014-001

- Do the rudder trim control system test
  AMM Task 27-21-00-735-22-001

If any of the above tests are unsatisfactory, visually inspect the rudder feel and centering unit cam roller bearing to verify whether it is rolling on the cam when the rudder pedals are moved. If it is sliding on the cam instead of rolling, the bearing must be replaced.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

named recipients. If you are not an intended recipient, you are hereby notified that any further review, copying, use or dissemination of this message is strictly prohibited. If you have received this message in error, delete it from your computer and/or other storage medium and notify the sender immediately.

28-Mar-2005 04:47:03 PM PST

4- Case of Overbank Follow up:
(Autopilot Overbank
29-03-05.

Dear Sir,
With refer to Boeing "MESSAGE NUMBER:1-1A7XEW", Required rudder tests in process. The operator notices that at 20:15:47, FDR data shows the follow:

Aircraft Roll 34.81
A/P "B" In Command
A/P Roll Mode LNAV

And with all previous condition autopilot still engaged till autopilot disconnected by the captain one second later.

Request:

Boeing Recommendation for the above situation.

5- BOEING COMPANY REPLY, 30-Mar-2005 02:01:38 PM PST

The operator has reviewed the FDR readout summary. The operator notes that FDR data point at time 20:15:47 reads:

> Aircraft Roll 34.81
> A/P "B" In Command
> A/P Roll Mode LNAV
> and with previous condition autopilot still engaged until disconnected by the captain one second later.

The operator also notes that the autopilot usually limits roll to approximately 30 degrees while engaged. The operator requests additional explanation regarding the recorded roll angle of 34.81 with the A/P engaged and LNAV selected.

Action:
1) Please review the aforementioned query and provide an explanation.
2) Please advise if any additional troubleshooting is required other than that provided in Activity 1-1A7XEW.

Reply:

Attached is an expanded plot of this event. The autopilot doesn't couple to the surface at the instant it is engaged. It first synchronizes the LVDT in the actuator to the surface position sensor in the quadrant. Also, FDR data is not sampled often enough to be sure of the exact timing; however it is probably the case that the detent solenoid that couples the autopilot to the surface was not actuated until the roll had already reached the maximum bank angle recorded. (The autopilot was engaged after the airplane had already established a roll rate to increase the bank angle to greater than 30 deg). In addition, for this engagement, the initial data point for CMD occurred just prior to the control wheel reaching zero. Since the surface was moving at the time of engagement, synchronization to that surface would take somewhat longer than normal.

We do not have any additional troubleshooting recommendations regarding this event.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

medium and notify the sender immediately.

30-Mar-2005 02:01:38 PM PST

6- Case of Overbank Follow up:
(Autopilot Overbank)
31-03-05

According to Boeing MESSAGE NUMBER:1-1A7XEW:
AMM 27-21-00 Task S 735-012-001carried out found normal, no finding.
AMM 27-21-00 Task S735- 014-001carried out found within limit.
AMM 27-21-00 Task S 735-22-001carried out found normal, no finding.
Also According to MESSAGE NUMBER:1-1AGX8Y
Autopilot "B" D. Defect cleared with no action taken.

7- Case of Overbank Follow up:
(Autopilot Overbank)
Sent: Thursday, April 07, 2005 11:04 AM

As the aircraft return, the Captain on command
recorded his report in the T. Log Book, autoflight was checked from FMC CDU using codes 100 and 300. No recorded faults found. Again after Boeing email was received autoflight checked using codes 100 and 300 on 7th of April,05 found one fault was recorded on flight -1 as follow
* ERROR FCC-B* P2 P SPM TRIP B-8776 A/P DISC.
Nothing else was recorded.

8- BOEING COMPANY REPLY, 13-Apr-2005 01:20:30 PM PST

REFERENCES:
Ref /A/ SR 1-57258797
1-1A4CR1

SUBJECT: Autopilot Overbank /
DESCRIPTION:
The following information has been received from the operator in response to Boeing request for flight fault information:

//QUOTE//As the aircraft return, the Captain on command recorded his report in the T. Log Book, Autoflight was checked from FMC CDU using codes 100 and 300. No recorded faults found. Again after ur. email was received autoflight checked using codes 100 and 300 on 7th of April,05 found one fault was recorded on flt -1 as follow
* ERROR FCC-B* P2 P SPM TRIP B-8776 A/P DISC.

Nothing else was recorded.//UNQUOTE//

ACTION:

Please review and advise if Boeing has any additional comments on the subject event or any additional troubleshooting/maintenance recommendations.

Reply:

The Bite fault note on 7 April is most likely not related to the event dated 19 March because the FCC will retain faults for only 9 flight legs.

The BITE message indicates the FCC recorded an internal fault. Also, the ERROR FCC-B indicates the fault was logged while the FCC was in the B channel and this computer was subsequently swapped to the A side when the BITE was interrogated.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

13-Apr-2005 01:20:30 PM PST

Appendix 2-2 Studies of other airplane incidents relevant to autoflight systems

Two cases of malfunctions related to Boeing 737-500 autopilot system were reported by one operator as follows:

I- CASE of “AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT”

1- BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/8/2004 2:25:33 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
One Operator reports that during descent with A/P A engages, VS mode selected and 1500 FPM selected on MCP panel airplane started a descent with a rate of 3000 FPM. Crew reported that this occurred two times. Crew reported that A/P operated normal.

Maintenance reported the following AFDS Bite results:

Possible Causes
Stab Trim M255
Elevator Pos. Sensor
Stab. Pos. Sen-1

Attached for review is DFDR data for the flight which started at 2000 GMT and ended at 2110 GMT.

ACTION:

The operator requests that Boeing review the submitted DFDR data and advise findings.

Attachment: autopilot.pdf Date 11/8/2004 1:38:59 AM

Commercial Aviation Services
The Boeing Company

11/8/2004 2:25:33 AM PST

2. BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/21/2004 2:55:20 AM PST

[MESSAGE NUMBER: 1-STLI4]
FROM: THE BOEING COMPANY

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /A/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. Boeing would be interested in knowing the altitude that was selected during the event and at what altitude the capture maneuver was initiated. Any available FDR data may be helpful in reviewing this event.

Regarding the A/P bite faults, Boeing would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an operator mechanic while in the flight deck of the airplane.

Please advise if the operator can support further troubleshooting using a cell phone in the flight deck where the FCC BITE can be performed via telecon with Boeing. If affirmative, please provide a time and phone number that Boeing can contact.

As reported previously, the operator has performed adjustments of the Ref /D/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Datum airplane is currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /D/ rods.

ACTION:

Please review and advise if Boeing concurs with the operator on replacement of the Ref /D/ rods.

Commercial Aviation Services
The Boeing Company

3- BOEING REPLY, EXCESSIVE RATE OF DESCENT
23-Nov-2004 11:42:51 AM PST

[SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /A/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised we would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an the operator mechanic while in the flight deck of the airplane.

As reported previously, the operator has performed adjustments of the Ref /D/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Datum airplane is currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /D/ rods.

ACTION:

Please review and advise if Boeing concurs with the operator on replacement of the Ref /D/ rods.

RESPONSE:

Last night, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

Commercial Aviation Services
The Boeing Company

4- BOEING REPLY, EXCESSIVE RATE OF DESCENT
11/30/2004 4:07:08 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /C/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised they would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an operator mechanic while in the flight deck of the airplane. As reported previously, the operator has performed adjustments of the Ref /E/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Ref /B/ advised that datum airplane was currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /F/ rods.

On 22-Nov-2004, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Ref /A/ advised that based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

The operator replaced and adjusted the Ref /F/ rods and released the airplane for service. On 26-Nov-2004 the crew reported that, with A/P "A" engaged and V/S of 2000 FPM selected, aircraft descent was 4,000 FPM. See attached log sheet for details. On 28-Nov-2004, crew reported that with A/P "A" engaged MCP ALT 33,000, FMA- ALT ACQ the airplane started a descent of more than 2000 FPM. Please see attached log sheet for details. Aircraft is currently operating using A/P "B" only.

Attached for review is DFDR data for the 26-Nov event flight leg. As reported above, the reported excessive descent rate was during descent.

The operator is requesting that Boeing review the data and report findings. The operator management has also requested on-site technical assist.

ACTION:

1. Please review the attached DFDR data and report findings.

2. Please advise if Boeing can provide on-site technical assist.

A response by 01-Dec is requested.

Commercial Aviation Services

The Boeing Company

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11/30/2004 4:07:08 AM PST

5- BOEING REPLY, EXCESSIVE RATE OF DESCENT
01-Dec-2004 01:52:43 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to the subject report, Ref /C/ advised that is possible that hysterisis in the actuator linkage can result in poor autopilot control. In addition, Boeing advised they would like to arrange for a convenient time when we could contact the operator and walk through some BITE tests with an the operator mechanic while in the flight deck of the airplane. As reported previously, the operator has performed adjustments of the Ref /F/ rods numerous times. After adjustment the aircraft would fly for a few days with no write-ups for the subject fault.

Ref /B/ advised that datum airplane was currently operating under MEL for A/P system A. Based on previous experience with this airplane, the operator is investigating whether to change the Ref /F/ rods.

On 22-Nov-2004, Boeing engineering was able to contact the operator personnel who were in the flight deck of the datum airplane. Ref /A/ advised that based on the BITE tests performed and discussions with the operator personnel, it was decided that replacement of both of the A/P elevator actuator rod assemblies (shown in Figure 401 on page 402 of AMM 22-11-26) is the next maintenance action to be taken. Following replacement, the Autopilot Elevator Actuator Adjustment (DFCS BITE Test) (TASK 22-11-26-825-047) must be performed (AMM 22-11-26/501). Note, when installing the rod assembly between the two actuators, the operator needs to tighten the locknuts and lock wire in place on the end.

The operator replaced and adjusted the Ref /F/ rods and released the airplane for service. On 26-Nov-2004 the crew reported that, with A/P "A" engaged and V/S of 2000 FPM selected, aircraft descent was 4,000 FPM. See attached log sheet for details. On 28-Nov-2004, crew reported that with A/P "A" engaged MCP ALT 33,000, FMA- ALT ACQ the airplane started a descent of more than 2000 FPM. Please see attached log sheet for details. Aircraft is currently operating using A/P "B" only.

Attached for review is DFDR data. As reported above, the reported excessive descent rate was during descent into SSH.

The operator is requesting that Boeing review the data and report findings. The operator management has also requested on-site technical assist.

ACTION:

1. Please review the attached DFDR data and report findings.

2. Please advise if Boeing can provide on-site technical assist.

Reply:

Boeing has reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing would recommend the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Commercial Aviation Services
The Boeing Company

01-Dec-2004 01:52:43 PM PST

6- BOEING REPLY, EXCESSIVE RATE OF DESCENT
03-Dec-2004 03:38:20 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:

This is to advise that Boeing has reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review.

Commercial Aviation Services
The Boeing Company

03-Dec-2004 03:38:20 PM PST

7- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
12/6/2004 5:56:58 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to Ref /D/, Ref /C/ advised that Boeing had reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing recommended the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Ref /B/ provided results of the above recommended tests.

Ref /A/ advised that Boeing had reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review. The operator has reviewed the Ref /A/ and /C/ responses and is requesting clarification regarding the intermittent trim command output from FCC A. As reported above, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. It was also verified that there were other times in the data where A did command trim in both directions, so FCC A was (is) capable of trim.

The operator is requesting further Boeing recommendations and on-site tech assist.

ACTION:

1. Based on the above data is replacement of the FCC A horizontal position sensor and sensor wiring check recommended?

2. Based on the above data, is an intermittent circuit between FCC A D1671B, pin 42, wire 102-20 to splice SP3677 a possible cause of the intermittent trim UP command?

3. Please advise any additional wiring checks to be performed.

Commercial Aviation Services
The Boeing Company

12/6/2004 5:56:58 AM PST

8- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
09-Nov-2004 03:42:22 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
The operator reports that, during descent with A/P A engages, VS mode selected and 1500 FPM selected on MCP panel airplane started a descent with a rate of 3000 FPM. Crew reported that this occurred two times. Crew reported that A/P operated normal.

Maintenance reported the following AFDS Bite results:

Possible Causes
Stab Trim M255
Elevator Pos. Sensor
Stab. Pos. Sen-1

Attached for review is DFDR data for the flight.

ACTION:

The operator requests that Boeing review the submitted DFDR data and advise findings.

Reply,

Boeing has reviewed the FDR data and we do not identify any unusual autopilot operation noted in the reviewed data. The selected V/S is not recorded and therefore it is difficult to determine how well the autopilot is tracking vertical speed. We produced a derivative of the airplane altitude to determine where in the flight the vertical speed was 3000 feet per minute or greater. The resulting vertical speed data plot did not confirm any flight segment that exhibited a vertical speed of 3000 feet per minute or greater. As an added note, if the winds change with altitude, the airplane vertical speed will be upset in the short term from that selected.

Commercial Aviation Services
The Boeing Company

09-Nov-2004 03:42:22 PM PST

9- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
07-Dec-2004 04:19:07 PM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
In response to Ref /D/, Ref /C/ advised that Boeing had reviewed the provided FDR data and pilot reports. During the event, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. Four seconds after B was engaged (elevator remained where it was) the stab drove for about 6 seconds which relieved the elevator about 1 degree. There were other times in the data where A did command trim in both directions, so FCC A was capable of trim.

Boeing recommended the following troubleshooting to verify the FCC stab trim interface as well as verification of the elevator position input to the channel A FCC:

Perform the DFCS Chapter 22 BITE Stab Trim rigging test, Elevator Rigging test (Both Single Authority and Dual Authority tests) and Mach Trim Rigging test. Verify that all the readings for these tests are within limits. As needed, Boeing will be available to support these checks by telecon. Please advise if the operator requests Boeing assistance by telephone during these checks and provide a contact time and number.

The noted condition could also be due to an incorrect FCC calculation of autopilot elevator authority upon which the trim thresholds are based. This calculation uses inputs from the ADCs. To help isolate this possible condition, we would recommend the operator swapping the left and right ADCs and IRUs.

Ref /B/ provided results of the above recommended tests.

Ref /A/ advised that Boeing had reviewed the FCC BITE data provided in fax dated 3 December and the data indicates all test results passed and FCC operation appears normal. Therefore Boeing has no further recommendations at this time and recommends using both A and B channel autopilots. In the event the condition occurs again, please provide a listing of any DFCS in flight faults, FCC Bite test results for elevator and stab rigging checks and FDR data for review. the operator has reviewed the Ref /A/ and /C/ responses and is requesting clarification regarding the intermittent trim command output from FCC A. As reported above, the elevator was out of nose up elevator authority while A was engaged, however no trim commands were output by A to pitch the airplane nose up. It was also verified that there were other times in the data where A did command trim in both directions, so FCC A was (is) capable of trim.

The operator is requesting further Boeing recommendations and on-site tech assist.

ACTION:

1. Based on the above data is replacement of the FCC A horizontal position sensor and sensor wiring check recommended?

2. Based on the above data, is an intermittent circuit between FCC A D1671B, pin 42, wire 102-20 to splice SP3677 a possible cause of the intermittent trim UP command?

3. Please advise any additional wiring checks to be performed.

Reply:

The stab position data is used in determining trim thresholds. We also agree that an open between FCC A D1671B pin 42 would result in the A channel FCC being unable to command a trim up. Therefore, replacement of the stab position sensor and sensor wire verification is recommended.

We understand that the airplane has returned to service and we have no further recommendations at this time.

Commercial Aviation Services
The Boeing Company

07-Dec-2004 04:19:07 PM PST

10- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
12/13/2004 6:06:11 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
Refs /A/ thru /E/ discuss subject events and troubleshooting accomplished by the operator and Boeing recommendations.

Pilot reported the following: "During descent to FL160, A/P "A" engaged, FMA displayed ALT ACQUIRE but airplane continued descent." Airplane returned with A/P "B" engaged and no faults were noted. Airplane has been operating using A/P "B".

The operator has provided the attached DFDR data for the event. Please note the altitude reported above may be 1,600 feet vs FL160.

The airplane is currently out of service for troubleshooting.

ACTION:

The operator requests that Boeing review the attached DFDR data and advise findings.

Commercial Aviation Services
The Boeing Company

12/13/2004 6:06:11 AM PST

11- BOEING REPLY, EXCESSIVE RATE OF DESCENT:
13-Dec-2004 11:06:19 AM PST

SUBJECT: AUTOPILOT REPORT OF EXCESSIVE RATE OF DESCENT

DESCRIPTION:
Refs /A/ thru /E/ discuss subject events and troubleshooting accomplished by the operator and Boeing recommendations.

Pilot reported the following: "During descent to FL160, A/P "A" engaged, FMA displayed ALT ACQUIRE but airplane continued descent." Airplane returned with A/P "B" engaged and no faults were noted. Airplane has been operating using A/P "B".

The operator has provided the attached DFDR data for the event. Please note the altitude reported above may be 1,600 feet vs FL160.

The airplane is currently out of service for troubleshooting.

ACTION:

the operator requests that Boeing review the attached DFDR data and advise findings.

RESPONSE:

For this event, it appears that when ALT ACQUIRE was engaged the elevator moved about 1 degree to slow the rate of descent and then remained flat at that value for the 10 seconds it was in the mode. It appears there was not enough elevator authority on the A side to finish pitching the airplane up, and it continued to slowly pitch down until the autopilot was disconnected.

Also during the acquire, the autopilot was not trimming the stabilizer. Since the flaps were at 1, the autopilot trims based on elevator position. Therefore, the autopilot probably could not move the quadrant far enough. Based on this and the previous event, it would appear that the A actuator does not have the required authority, for whatever reason.

Commercial Aviation Services
The Boeing Company

II- CASE of AUTOPILOT OVERBANK

1- Case of Overbank Follow up:

Model: 737 - 500

Pilot Report:

During Departure with LNAV engaged, when selecting A/P "B", A/P "B" engaged then disengaged. After satisfying F/D again A/P selected then autopilot gives more than 35 deg. bank angle and increasing. A/P disconnected again followed by F/D Pitch bar out of view. F/D switches recycled off-on.

After Flap retraction and with aircraft was leveled A/P selected again operates normally (A & B)

Maintenance Action:

- Autoflight system checked on ground from MCDU according to M.M. found operating normal.
- Last flight faults checked, found no faults recorded.
- Both IRS checked found OK
- Flight data recorder removed for read out and aircraft released for flight.
- Snag not repeated on the next flights but FDR read out for the subject flight shows that autopilot exceeds bank angle limitation.
- A/P "B" was deactivated and considered A/P "B" D. Defect according to MEL.

N.B
The airplane has a history in flight control problems, Boeing have the full details.
(Subject Flight FDR raw data available if needed)

2- BOEING COMPANY REPLY
3/27/2005 4:30:18 AM PST

Please do not reply. This message is the acknowledgement of your request.

Your Service Request has been received by The Boeing Company. Your request will be reviewed and a response provided in accordance with your request. Thank you for your inquiry.

SUBJECT: Autopilot Overbank /
DESCRIPTION:
T he flight crew reported the following:

During departure with LNAV engaged, AP "B" selected, the AP "B" engaged then disengaged. After satisfying F/D, again AP selected. At UTC 20:14 the autopilot gave more than 35 degree bank angle and increased. A/P disconnected followed by F/D pitch bar out of view, F/D switches recycled. Flap retraction and leveled, AP selected and operation normal.

Maintenance Action:
the operator maintenance checked on ground Autopilot system from MCDU and per MM no findings. Both IRS checked no finding. FDR removed for analysis and plane released back on flight line. Snag didn't reappear on the next flight. According to FDR the subject airplane had an autopilot exceeds bank angle limitations.
The operator deactivated the AP "B" and considered the AP "B" defected according to MEL.
The FDR raw data is available for Boeing review if required.

Action:
The airplane has a history of heavy flight control per Ref /A/ SR.
The subject Airplane is currently AOG for troubleshooting.
Please review the above information and advise the operator with any recommended troubleshooting.

Commercial Aviation Services
The Boeing Company

BOEING PROPRIETARY

3/27/2005 4:30:18 AM PST

3- BOEING COMPANY REPLY
28-Mar-2005 04:47:03 PM PST

REFERENCES:
Ref /A/ SR 1-57258797

SUBJECT: Autopilot Overbank /
DESCRIPTION:
The flight crew reported the following:

During departure with LNAV engaged, AP "B" selected, the AP "B" engaged then disengaged. After satisfying F/D, again AP selected. At UTC 20:14 the autopilot gave more than 35 degree bank angle and increased. A/P disconnected followed by F/D pitch bar out of view, F/D switches recycled. Flap retraction and leveled, AP selected and operation normal.

Maintenance Action:
the operator maintenance checked on ground Autopilot system from MCDU and per MM no findings. Both IRS checked no finding. FDR removed for analysis and plane released back on flight line. Snag didn't reappear on the next flight. According to FDR the subject airplane had an autopilot exceeds bank angle limitations.

The operator deactivated the AP "B" and considered the AP "B" defected according to MEL.
The FDR raw data is available for Boeing review if required.

ACTION:

The airplane has a history of heavy flight control per Ref /A/ SR.

The subject Airplane is currently AOG for troubleshooting.
Please review the above information and advise the operator with any recommended troubleshooting.

As a follow-up, the operator attached the FDR data to Message Number: 1-1A4J4N.

RESPONSE:

We have analyzed the flight data recorder data provided by the operator, and are providing that analysis, followed by troubleshooting suggestions. The figures referred to in the analysis are provided as attachments to this response.

FDR Analysis

Analysis of the FDR data indicate that the overbank resulted when the pilot released the wheel, possibly to engage the autopilot, while the airplane had been trimmed with approximately 1.5 degrees of nose-left rudder pedal. Figure 1 presents the lateral and directional data for the event; for reference, the longitudinal parameters during the event are provided in Figure 2, although they did not play a significant role in the overbank.

The airplane performed a flaps 5 takeoff, becoming airborne at time 546 according to the air/ground logic. The airplane climbed out at 160 KCAS and shortly after lift off initiated a left turn from heading 295 towards heading 170. The wind was out of heading 050, increasing to about 25 knots in the air - this would constitute a quartering right tailwind transitioning to a quartering left tailwind. Note that FDR wind data are not valid on the ground.

At liftoff, the control wheel was deflected to about 25 degree right, and held at that deflection to maintain wings level. As the left turn was initiated, wheel was relaxed back to neutral and then deflected slightly left. At time 570 the wheel was relaxed to neutral and the A/P "B" was engaged - at this time the airplane had zero control wheel displacement but was rolling left at about 2.5 deg/sec. After about 1 sec, the A/P "B" disengaged. The control wheel was then deflected to the right, again to about 25 degrees, and arrested the roll at 30 degrees of left bank. At time 592 the control wheel returned to neutral and the A/P "B" channel was engaged again. As the wheel returned to neutral, the airplane again began to roll left at about 2 deg/sec. At time 597 the A/P "B" disengaged a second time and the CWS ROLL discrete (not shown) briefly engaged for 1 frame. Control wheel was deflected to 40 degrees right, the bank angle returned to zero and then continued right to about 4 degrees, then wheel was relaxed back to about 20 degrees right to hold bank angle between 5-8 degrees right.

During the entire event, from liftoff to the CWS engage and the roll back to 5-8 degrees right, the airplane appears to have been in a small nose-left sideslip. Rudder pedal indicates about 1.5 degrees nose left, and rudder position indicates about 2.7 degrees nose left. Furthermore, lateral acceleration persisted throughout the event at about -.03 g's, another indication of small sideslip angle. A simulation of the event confirms that, for the airspeed, altitude, and airplane configuration, a rudder pedal input of 1.5 degrees would give about 2.7 degrees of rudder and would require about 26 degrees of right wheel to balance. As the airspeed increased (FDR time 605 and on) the rudder blew down, and the amount of wheel required to balance reduced to about 20 degrees.

Figure 3 shows the takeoff roll. At time 505, the engines began to spool up - prior to this, the rudder pedal and rudder position parameters are both very close to zero (neutral). Shortly afterwards, several large pedal and rudder deflections occurred, accompanied by changes in heading. This is not unusual at the beginning of a takeoff roll and generally indicates that the pilot was aligning the aircraft on the runway centerline. By time 530 the rudder pedal deflections had subsided, but the rudder pedal position remained approximately at 1-2 degrees nose-left. The reason for this is unknown, but the deflection of pedal is confirmed by the accompanying rudder deflection of approximately 2-3 degrees nose left.

Figure 4 shows the FDR data after the event. At time 690, the flaps had been retracted to UP, and the airplane was just completing a left turn to heading 170, with bank angle returning to neutral. At this time, the pedal remained deflected at 1.3 degrees nose left, the rudder position was 2.2 degrees nose left, and 20 degrees of right wheel were required to hold the wings level. At this airspeed (now 205 KCAS) the simulation again indicates that this is consistent. As airspeed began increasing toward 250 KCAS, the rudder pedal and rudder position slowly neutralized; this was likely the result of manual trim adjustments by the crew, as the rudder appears to return in steps similar to the trim rate (note the expanded scale on rudder pedal on Figure 4). During the descent, as airspeed increased, the data indicate that the rudder pedal and rudder position remained near neutral, further suggesting that the situation was corrected during the cruise.

Conclusion

The FDR data indicate that PT561 experienced an overbank during an attempted autopilot engage because the airplane was in a small nose-left sideslip as the result of rudder pedal being deflected to approximately 1.5 degrees nose left. The reasons for this are unknown and cannot be determined from the FDR data, but the trim likely arose either from crew trim inputs during the takeoff roll (possibly inadvertent) or from something sticking in the rudder feel and centering unit. The simulation confirms that the sideslip resulting from the pedal input would have required approximately 25 degrees of right control wheel deflection to maintain wings level flight, as indicated by the FDR data. During each attempt to engage the "B" autopilot, the wheel was released to neutral and the airplane rolled at between 2 and 2.5 deg/sec as a result of the sideslip-induced roll.

Past experience with lateral trim issues on 737's would indicate that flap rigging was not a factor, as the roll that can be produced by flap mis-rigging is not nearly large enough to require 25 degrees of control wheel. Small sideslip angles, on the other hand, can produce significant roll asymmetries.

From the data provided, the autopilot was working normally.

We suggest that the operator accomplish the following troubleshooting:

- Do a test of the rudder centering
  AMM 27-21-00 Task S 735-012-001

- Do a test of the rudder pedal forces
  AMM 27-21-00 Task S 735-014-001

- Do the rudder trim control system test
  AMM Task 27-21-00-735-22-001

If any of the above tests are unsatisfactory, visually inspect the rudder feel and centering unit cam roller bearing to verify whether it is rolling on the cam when the rudder pedals are moved. If it is sliding on the cam instead of rolling, the bearing must be replaced.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

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28-Mar-2005 04:47:03 PM PST

4- Case of Overbank Follow up:
(Autopilot Overbank
29-03-05.

Dear Sir,
With refer to Boeing "MESSAGE NUMBER:1-1A7XEW", Required rudder tests in process. The operator notices that at 20:15:47, FDR data shows the follow:

Aircraft Roll	34.81
A/P "B"	In Command
A/P Roll Mode	LNAV

And with all previous condition autopilot still engaged till autopilot disconnected by the captain one second later.

Request:

Boeing Recommendation for the above situation.

5- BOEING COMPANY REPLY, 30-Mar-2005 02:01:38 PM PST

The operator has reviewed the FDR readout summary. The operator notes that FDR data point at time 20:15:47 reads:

> Aircraft Roll 34.81
> A/P "B" In Command
> A/P Roll Mode LNAV
> and with previous condition autopilot still engaged until disconnected by the captain one second later.

The operator also notes that the autopilot usually limits roll to approximately 30 degrees while engaged. The operator requests additional explanation regarding the recorded roll angle of 34.81 with the A/P engaged and LNAV selected.

Action:
1) Please review the aforementioned query and provide an explanation.
2) Please advise if any additional troubleshooting is required other than that provided in Activity 1-1A7XEW.

Reply:

Attached is an expanded plot of this event. The autopilot doesn't couple to the surface at the instant it is engaged. It first synchronizes the LVDT in the actuator to the surface position sensor in the quadrant. Also, FDR data is not sampled often enough to be sure of the exact timing; however it is probably the case that the detent solenoid that couples the autopilot to the surface was not actuated until the roll had already reached the maximum bank angle recorded. (The autopilot was engaged after the airplane had already established a roll rate to increase the bank angle to greater than 30 deg). In addition, for this engagement, the initial data point for CMD occurred just prior to the control wheel reaching zero. Since the surface was moving at the time of engagement, synchronization to that surface would take somewhat longer than normal.

We do not have any additional troubleshooting recommendations regarding this event.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

medium and notify the sender immediately.

30-Mar-2005 02:01:38 PM PST

6- Case of Overbank Follow up:
(Autopilot Overbank)
31-03-05

According to Boeing MESSAGE NUMBER:1-1A7XEW:
AMM 27-21-00 Task S 735-012-001carried out found normal, no finding.
AMM 27-21-00 Task S735- 014-001carried out found within limit.
AMM 27-21-00 Task S 735-22-001carried out found normal, no finding.
Also According to MESSAGE NUMBER:1-1AGX8Y
Autopilot "B" D. Defect cleared with no action taken.

7- Case of Overbank Follow up:
(Autopilot Overbank)
Sent: Thursday, April 07, 2005 11:04 AM

As the aircraft return, the Captain on command
recorded his report in the T. Log Book, autoflight was checked from FMC CDU using codes 100 and 300. No recorded faults found. Again after Boeing email was received autoflight checked using codes 100 and 300 on 7th of April,05 found one fault was recorded on flight -1 as follow
* ERROR FCC-B* P2 P SPM TRIP B-8776 A/P DISC.
Nothing else was recorded.

8- BOEING COMPANY REPLY, 13-Apr-2005 01:20:30 PM PST

REFERENCES:
Ref /A/ SR 1-57258797
1-1A4CR1

SUBJECT: Autopilot Overbank /
DESCRIPTION:
The following information has been received from the operator in response to Boeing request for flight fault information:

//QUOTE//As the aircraft return, the Captain on command recorded his report in the T. Log Book, Autoflight was checked from FMC CDU using codes 100 and 300. No recorded faults found. Again after ur. email was received autoflight checked using codes 100 and 300 on 7th of April,05 found one fault was recorded on flt -1 as follow
* ERROR FCC-B* P2 P SPM TRIP B-8776 A/P DISC.

Nothing else was recorded.//UNQUOTE//

ACTION:

Please review and advise if Boeing has any additional comments on the subject event or any additional troubleshooting/maintenance recommendations.

Reply:

The Bite fault note on 7 April is most likely not related to the event dated 19 March because the FCC will retain faults for only 9 flight legs.

The BITE message indicates the FCC recorded an internal fault. Also, the ERROR FCC-B indicates the fault was logged while the FCC was in the B channel and this computer was subsequently swapped to the A side when the BITE was interrogated.

Commercial Aviation Services
The Boeing Company

If attachments are referred to, and are not present, then the recipient should contact their Field Service Representative to obtain a copy.

13-Apr-2005 01:20:30 PM PST

2.6. Crew Behavior

Note:

All crew behavior subcommittee work has been included in the report with no differentiation between preliminary and otherwise.

The report reflexes the interpretation of the Egyptian Investigation Team and specialized advisors.

2.6.1 Flash Airlines Flight 604 Investigation
Crew Behavior Subcommittee

<u>Definition of spatial disorientation</u>
Spatial disorientation is an incorrect perception of attitude, altitude or motion of one's own aircraft relative to the position of the Earth.

Type I spatial disorientation:
Unrecognized spatial disorientation. No conscious perception of SD.
Distractions are often antecedents to the accident. Crash with no distress or concern expressed. No mayday or other than routine communications. Unusual or inappropriate aircraft attitude, but pilot does not make any appropriate corrective action. Pilot is apparently oblivious to the situation.

Type II recognized:
Conscious manifestation of a problem. Pilots often incorrectly refer to this experience as vertigo. Pilot recognizes conflict between perceived and intended or expected attitude. Can assume that the instruments are operating incorrectly. Might not properly react because of difficulty accepting indicated correct control input or might just be puzzled about the situation. Confusion might persist after recovery and lead to compounding of SD problem.
{Veronneau, S.J.H. & Evans, R.. (2004). Spatial disorientation mishap classification, data and investigation. Previc, F.H. & Ercoline, W.R. (Eds) Spatial disorientation in aviation. American institute of Aeronautics and Astronautics.}

<u>Conditions for establishing spatial disorientation</u>
1. Presence of inaccurate or misleading vestibular cues.
2. Absence of visual cues or presence of misleading visual cues.
3. Presence of a distraction capable of drawing attention away from attitude displays.

<u>Examination of evidence pertaining to specific phases of the accident</u>
1. From the roll input that initiated a right roll from wings level (from around time 104) through the statement by the Capt, "how turning right", (around time 02:44:37), the committee agrees that the above three conditions are met, and it is therefore possible that the Capt was experiencing type I Spatial Disorientation.
2. From the statement by the Capt, "How turning right", to the beginning of sustained left roll (around time 158), evidence for orientation or disorientation is inconclusive given currently available data.
3. After the first officer says "no autopilot commander" and sustained left control inputs begin the committee agrees that there is evidence that someone was properly oriented and manual recovery of the aircraft was initiated.
4. The committee agrees that there is no evidence suggesting spatial disorientation on the part of the first officer.
5. The committee agrees that the flight crew exhibited some positive CRM- related behaviors during the flight; however, further analysis in this area is required.

<u>Closing Comments</u>
This is a preliminary report. More work is needed to comprehensively address all human factors issues relevant to this accident, as needed.

2.6.2 Flash Airlines Flight 604 Investigation, Crew Behavior Subcommittee August 2004:

According to the meeting held on Aug. 23 – 26, 2004 and attended by representatives from NTSB, BEA and Boeing. The committee agreed that the Captain was possibly experiencing “Type I Spatial Disorientation” in the 1st stage of the accident.

In the 2nd stage the evidence of “Spatial Disorientation Type I” is inconclusive.

In the 3rd stage there is no evidence of this disorder.

On 15 February, 2005 a message was received from NTSB including analysis of the Captain Behavior.

The scenarios included the word “Confusion “and not “Spatial disorientation type I “.

Here is a comparative analysis of different labels of the Captains behavior.

Confusion:

By definition confusion means: a state of mild disturbance of consciousness where the person is perplexed and fails to distinguish properly different stimuli around him. It is caused by internal factor as illness; sever fatigue, drugs … etc.

Differentiation from similar conditions can be shown in the following table:-

	Duration	Onset & Termination	Other crew members	Appropriate corrective action	Response to calls	Tone of speech	Reaction time	Insight	Anxiety	Astonishment	Rate of conversation	Orders
Confusion	Long	Gradual	Not affected	Slow	Slow	Slurred	Prolonged	Partial	Probable	None	Few	Few
Spatial disorientation type I	Short	Sudden	May be affected	None	N.	N.	N.	None	None	None	N.	N.
Distraction	Short	Sudden	Usually affected	Yes	Can be normal	May be anxious	N.	N.	Yes	High	Few	Few
Mistake	Short	Sudden	Not affected	Yes	N.	N.	N.	None	None	None	N.	N.

Captain:

We apply the above table to the circumstances of the accident. The highest probability is that the captain suffered from distraction accuracy during the 1st stage only.

In favor of distracting:

The 1st part of C.V.R. shows the talk and behavior of captain is completely normal.

The captain was the 1st to attract attention of the rest of the crew that something wrong is happening in the airplane "*see what the airplane did* ".

This distraction could not be detected in the 2nd or 3rd stage.

This was shared by other crewmembers, as they assisted the captain in the same direction. Their observation and responses were centered on "right bank" and "autopilot".

Captain was alert with good concentration in the 2nd and 3rd stage as shown by his orders, responses and 3 appropriate actions taken (to the left):

- 1st action Lt input after words "How Right" يميني إزاي
- 2nd action Lt input "OK come out"
- 3rd action Lt input "OK come out"

During 1st stage (critical stage) there was signs indicating astonishment (How Right) also signs of Hesitation (turning right sir).

Crew members:

Include 3 persons Captain, 1st officer and extra crew 1.

Their behavior can be analyzed through two stages of C.V.R. record.

1st period (Pre-critical)

There were talks in between all crew members and between crew members and A.T.C. and attendant. Answers and comments are immediate and correct pointing to normal orientation and concentration. The mode and content of sentence show no evidence of disturbance of mood or intellectual functions. The conversations were calm and decisive with no evidence of anxiety or tension. There is no evidence of Euphoria or depressed mood.

2nd period (Critical)

Starting by the phrase "Eddilo" (time 2:44:1) this was followed in few seconds by an important observation of the captain indicating that something is going wrong with the airplane.

This was followed by a l---- period of hesitation, astonishment lasting for less than ten seconds.

These manifestations were mostly evident with the captain. This period ended by the captain saying "how turning right ", then " OK come out ".

During this stage of hesitation the other crew members F.O. & extra crew 1 their comments and answers were correct but the responses are anxious and rapid.

All crewmembers are anxious during this period of hesitation and astonishment ended by the captain saying "how turning right ".

All these problems were corrected to normal in the remaining period (after OK come out) according to the table of differentiation these are manifestation of distraction.

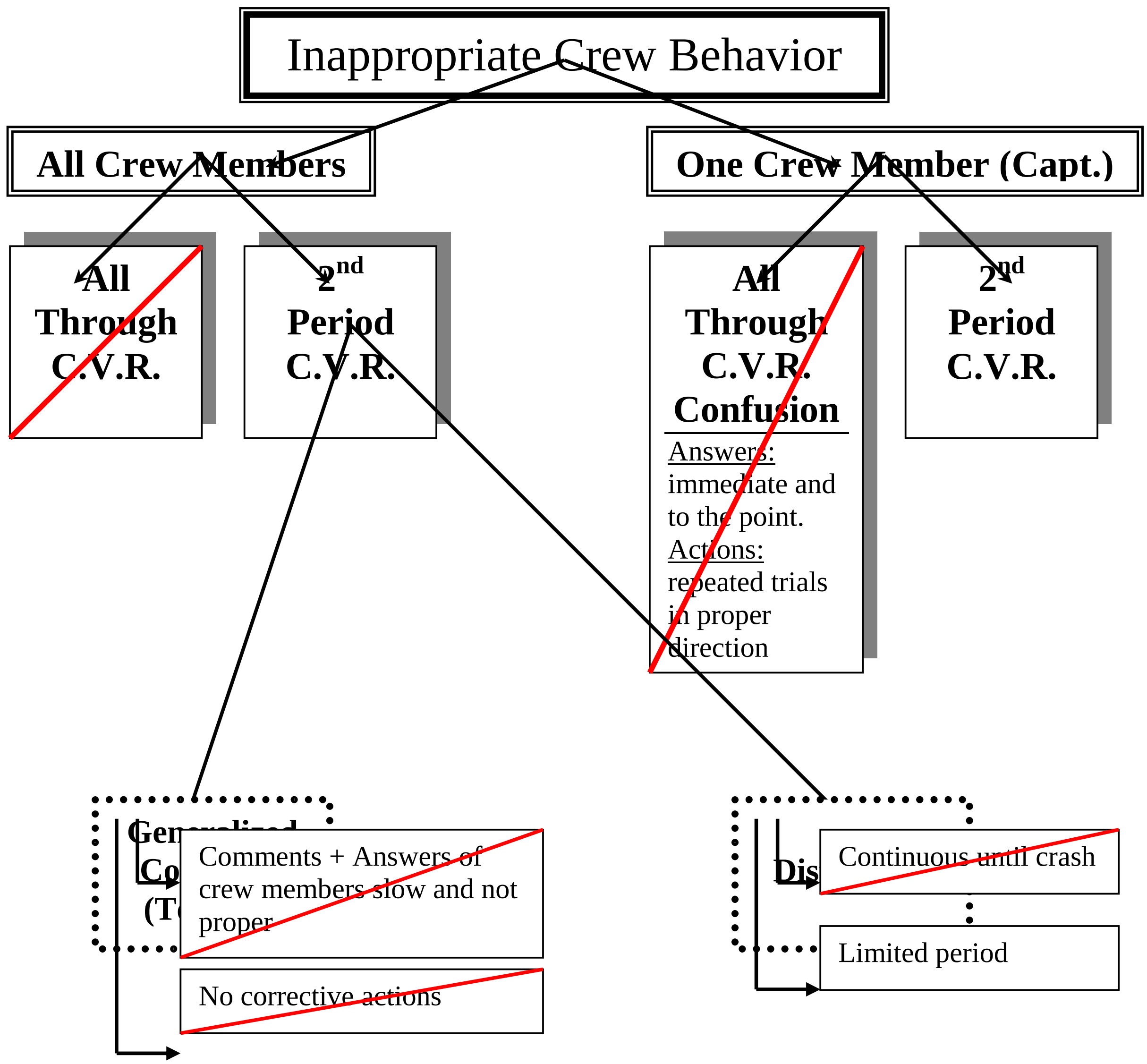
Both F.O. and extra crew 1 did not contradict the captain's orders or actions until the end of accident. This shows that in their estimation the captain was acting in the proper way.

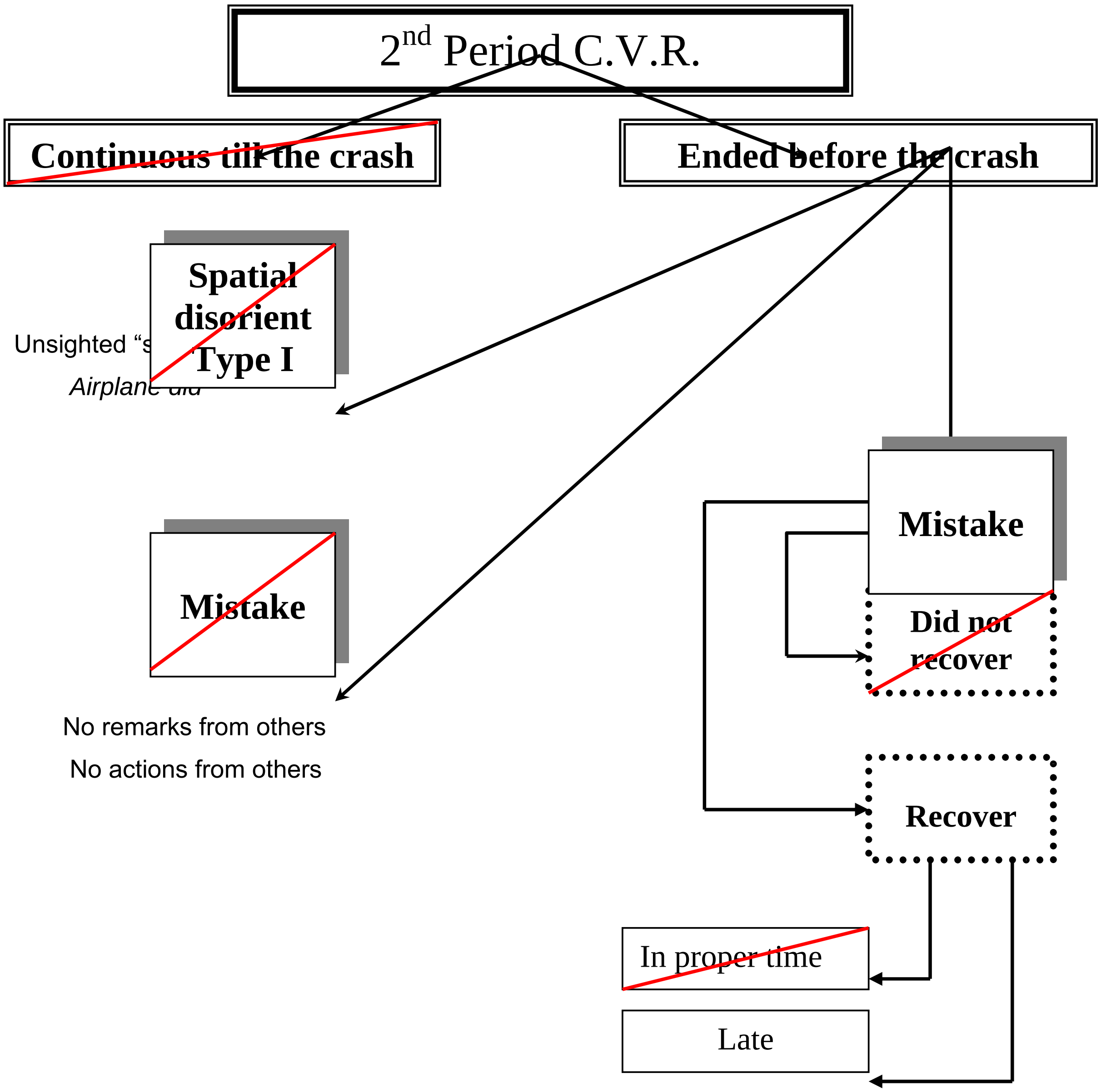
If they felt he is wrong they would have (at least) suggest any other action.

As the crew were in stress this logically abolishes the respect of seniority.

If captain is acting wrongly they would have screamed loudly and aggressively there is no evidence of this (C.V.R.).

The extra crew 1 is an experienced pilot – Age 42 – (4000 h. flight)


Inappropriate Crew Behavior
All Crew Members
One Crew Member (Capt.)
All Through C.V.R.
2nd Period C.V.R.
All Through C.V.R. Confusion
Answers: immediate and to the point.
Actions: repeated trials in proper direction
2nd Period C.V.R.
Comments + Answers of crew members slow and not proper
No corrective actions
Continuous until crash
Limited period


2nd Period C.V.R.
Continuous till the crash
Ended before the crash
Spatial disorient Type I
Mistake
No remarks from others
No actions from others
Mistake
Did not recover
Recover
In proper time
Late

2.6.3 Flash air CBS Sub-group comments (25 August 2005)

Flash Air CBS Sub-group Working Document

24 August 2005

Initial Factors for which we have evidence

Factors Conducive to a Fatigued State – Time of day, cumulative work hours, 2(3) early morning departures

Factors Conducive to the Occurrence of Spatial Disorientation- Dark night,, previous Russian ADI experience, low time in type,

Factors Conducive to a Authority Gradient Between Captain and Copilot: (a) large differences in aviation experience (Captain 7000 hours, copilot 800 hrs), (b) percieved differences in social status/rank (Captain retired Air Vice Marshal with prior military career, Copilot just beginning his career in aviation with no prior distinction), (c) large differences in age (53 years / 25 years)

The following facts exist

- No training in spatial disorientation, upset recovery, automation, or CRM training provided by Flash Airlines (not required by civil aviation)
- Captain and Copilot low time in type (automation, handling)

Pre takeoff events

Checklist execution and handling of interruptions- generally good

**Captain's questions regarding Cairo ceiling info provided by ATC – CRM issue because he never resolves the F/O and observer uncertainty on this issue

Discussion between Capt. and engineer regarding unknown aircraft discrepancy - Not enough information to evaluate crew handling of this issue

Takeoff briefing "Standard briefing." Airmanship and CRM issue – lack of professionalism and it is the first departure of day

Pre takeoff events

[Before takeoff Checklist– item change for CVR, he did say “Before takeoff check….”-transcript]

2:41:34 - Captain’s request that F/O verify departure altitude FO not repeating question to ATC initially- possible fatigue and workload factor in not hearing captain’s request to check altitude CRM - issue because of F/O’s responses.

Captain’s request that F/O verify departure altitude Fatigue or confirmation issue– Captain should have heard altitude during initial clearance from ATC. Also, altitude was already set in MCP heading.

Departure events

**Captain is possibly not using boom mike – professionalism/CRM or possible unintentional error unchallenged by F/O.

Captain's first heading select call occurred below 10 feet AGL, Error in sequence as he called it early. Possible fatigue issue. TOGA display inoperative proceedure called for heading select at 400 feet.

Departure events

- Failure to track pitch and airspeed deviations (22 degrees up and -30 knots speed error/eventually 35 knots) – indicators of distraction and possible fatigue. Failure to track FD for 15 seconds prior to autopilot call (25 seconds total), indicative of distraction (attention directed elsewhere), SD in pitch axis (following vestibular cues) – other items or inattention (from attempt to engage autopilot for last 10 seconds) or slow response

- Attempted autopilot engagement, disengagement, and subsequent mode changes- created a period of distraction. CRM issues - communications unclear during event, inadequate post event clarification; FO issued duties of after takeoff checklist and this item- after takeoff checklist completed not heard – could be reason for FO actions during this time

After takeoff issues

- Beginning of right bank- (at time of heading select statement)--- Lack of a quick correction indicates distraction from the attitude indicator, vestibular perceptions are inaccurate, captain does not realize airplane is entering a right bank, and the result is spatial disorientation for the captain. Distraction could result from any of the following causes: Fixation on a particular display or display element, following a shortest-distance flight director command (from undocumented MCP heading selection), lack of attention to roll and pitch with corresponding trim effects, or reflection on problems that may have occurred or the previous autopilot sequence or unexpected aircraft response or focusing on something else. CRM issue - FO not issuing timely notification of undesired bank – fatigue, distraction, authority gradient [Note: look at possibility of “step function” leans.]

- Captain’s statement “See what the aircraft did” and lack of verbal response from F/O – CRM, fatigue issues. Captain has never clearly communicated what is going on since the time of his exclamation during the attempted autopilot engagement sequence. Continued right bank indicates he is still distracted from airplane control.

After takeoff issues

- Lack of communications of the crew during right turn –CRM -regarding unintentional right turn or unsuccessful attempt to maintain wings level at 140 heading -22 seconds- fatigue (inattention/distraction)

- “Turning right sir” exchange- Indicates Captain is spatially disorientated and F/O is not. Captain’s reaction accompanying reply, “Ah” is to increase roll to the right for first 4 seconds – indicates SD, possible fatigue,, fixation on inappropriate element of attitude display (e.g., roll pointer) / perceptual reversal.

- “How turning right” exchange- attempt to get an explanation from self or FO. Indicates SD is being recognized and is transitioning to type 2 SD, captain attempting to resolve conflict between his internal perception of attitude and the attitude shown on the EADI (Took 18 to 20 seconds for resolution in one previously documented accident, or 27 to 33 seconds to resolve and stabilize airplane from climbing right attitude in Air Force study). No FO statement indicates inadequate CRM.

Departure events

“Ok, come out”- expression of necessity of action / statement of desired outcome. During an area of generally sustained inputs in the wrong direction there is aileron movement for a period of 3 seconds in the correct direction of movement with movement past neutral for 1 second.

Overbank callout by FO- Indicates CRM issues – late callout, (not directive).

Capt response to first overbank callout – no direct response and may not have been need based on his previous words

Wheel oscillations for the next 13 seconds, predominantly to right –   oscillating wheel motions predominantly in inappropriate direction resulting in increased right bank.

“Autopilot” (Capt) – Suggests captain is looking for a solution to correct the overbank problem and/or spatial disorientation (bailout mechanism). Similar to previous statement autopilot engage, differs from previous comments describing problems (“edillo”, “see what the ...”) Command is inappropriate because the AP is not intended to recover from unusual attitudes. (Ref FCTM 1.30).

“Autopilot in command” (FO) - automatic response (when FO pushes AP button) following captain’s order

Departure events

“tsk, tsk” sound – vocalization by FO expressing disapproval or uncomfortable with situation.

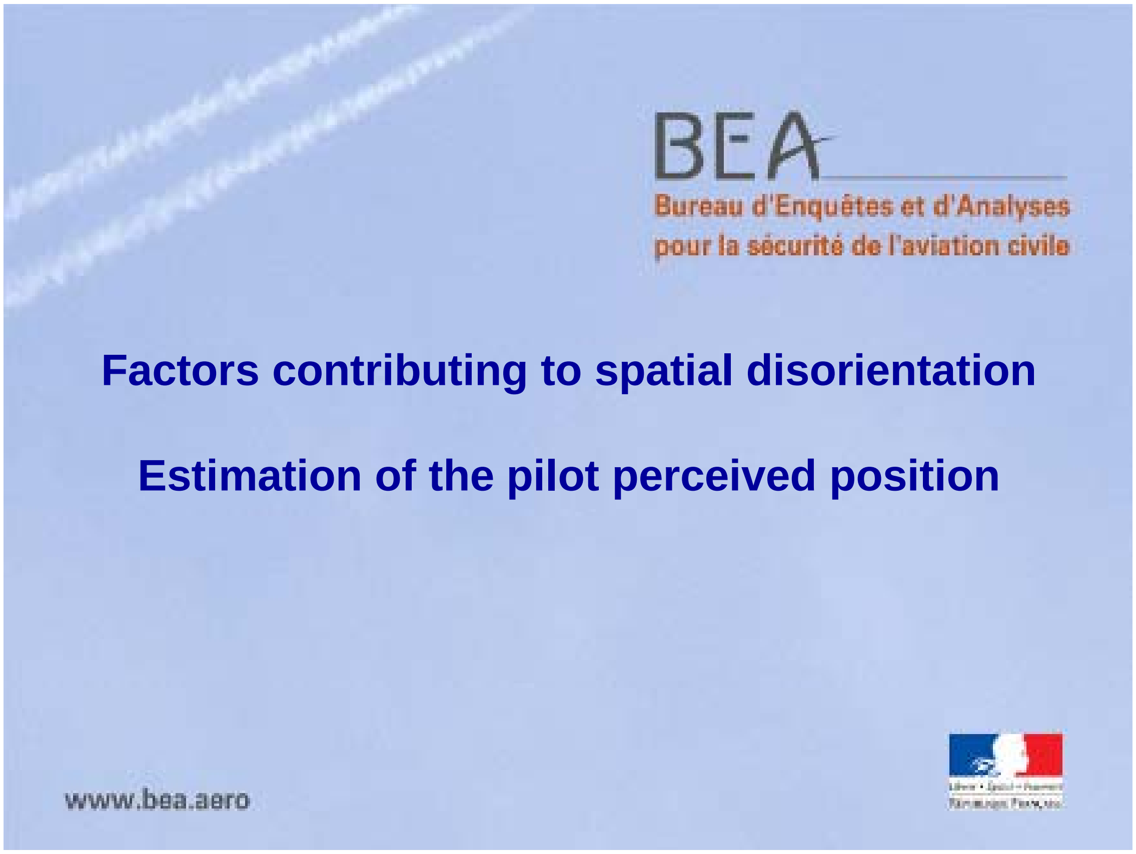
“Overbank, Overbank, Overbank” by FO. F/O continues to provide same observational callout, and does not escalate his assertiveness by asking questions, providing suggestions, issuing commands, or taking control of the airplane. Indicates possible problems with – inexperience, authority gradient

“No autopilot commander” - First officer is observing and communicating that autopilot is not connected.

Retard power calls from observer – comment very late in sequence. Observer did not comment on unsafe condition developing in the flight deck until very late in the sequence

Recovery effort - appropriate roll and power inputs, but pitch inputs were insufficient to recover within remaining altitude.

2.6.4 Major factors contributing to Spatial Disorientation (Contribution by BEA)



Major factors contributing to Spatial Disorientation

- ***Flight environment***
  - Night flying
    - Absence of clear references (lack of clear horizon, ground/sky confusion…)
    - Erroneous false horizons (shoreline, sloping cloud bank…)
    - Isolated light sources
  - IFR flights
    - Transfer from external visual to instruments cues
  - Flight over featureless terrain
    - False perception of height

- ***Aircraft Factors***
  - Inadequate or inoperative instruments
  - Visibility of instruments

BEA

Major factors contributing to Spatial Disorientation

- ***Flight maneuvres***
  - Prolonged angular motion
    - sustained motion not sensed
    - somatogyral illusions on recovery
    - no sensation of bank during coordinated turn
    - cross-coupled and "g-excess" illusions if head movement is made while turning
  - Subthreshold changes in attitude
    - "the leans" induced on recovery

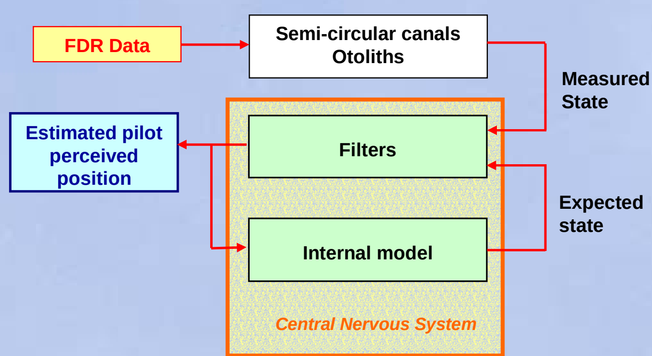
- ***Air crew Factors***
  - Training, flight experience, and proficiency in instrument flight
  - Physical and mental health
  - Alcohol and drugs
  - Workload and capacity
    - Fatigue
    - Circadian disrhhythmia (jet lag)
    - Additional communications or tasks

BEA

ESTIMATED PILOT PERCEIVED POSITION

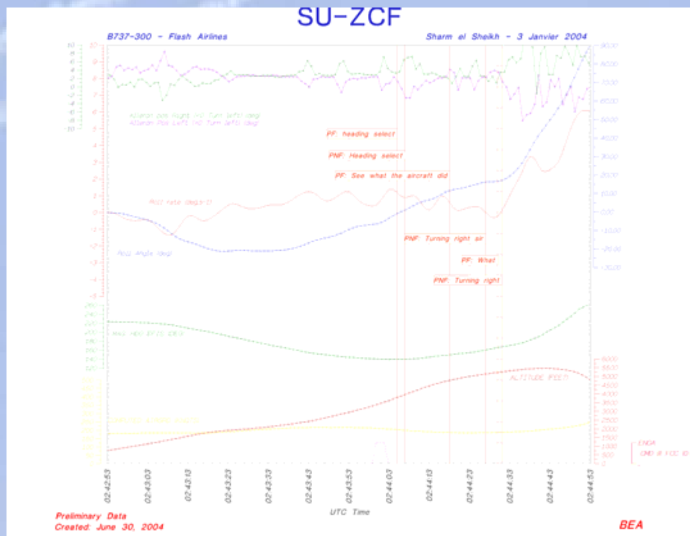
Merfeld, "Observer Theory Model", 2001

- Source:
  - FDR data
- Limitations:
  - No visual orientation data, no audio, proprioceptive inputs
  - Individual differences – especially threshold
  - Possible head movements not taken into account
- Results:
  - Estimated pilot perceived position



BEA

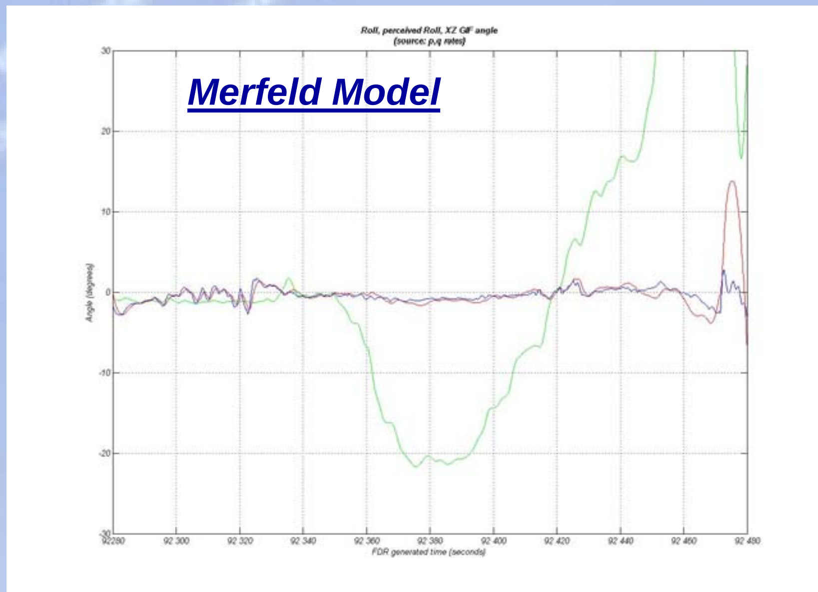
Roll, Roll rate and aileron movements



- ➢Possible sub-threshold roll input
  - ⇨Inducing "the leans" at the end of the turn
- ➢Prolonged angular motion
  - ⇨Approximately 50 seconds of slow roll rate to the right
  - ⇨Large aileron input to the right at the end of the slow roll rate

BEA

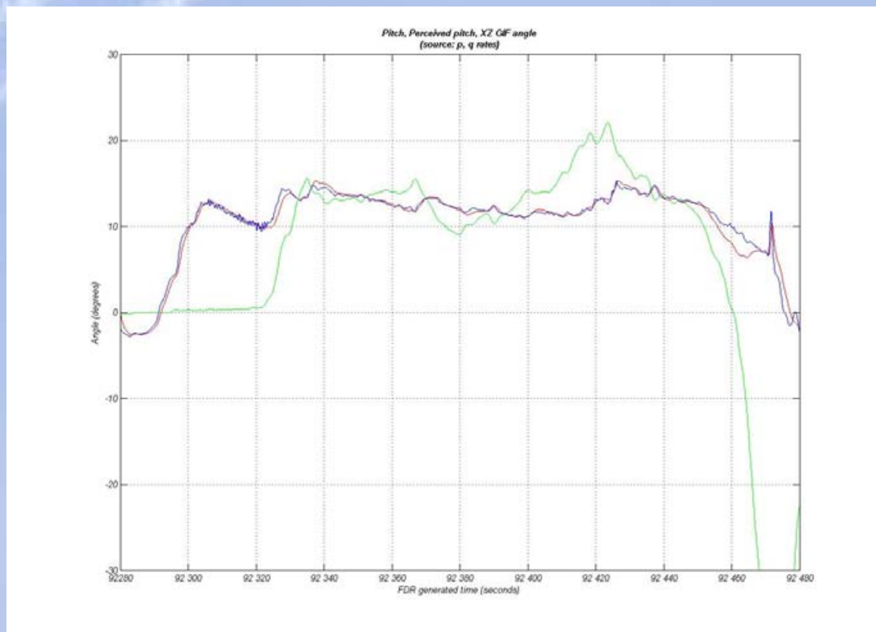
Roll, YZ GIF angle, Perceived Roll



- ➢Low sensation of the sustained and prolonged roll rate to the right
- ➢Low sensation of bank during turn to the right
  - ⇨Confirmation of Mc GRATH results

BEA

Pitch, XZ GIF angle, Perceived Pitch



BEA

2.6.5 Fatigue study in collaboration (Contribution by BEA)

LAA :

Laboratory of Applied Anthropologie

part of medicine university PARIS V

Activity : ergonomics

–Biomecanics,

–Psychophysiology,

–chronobiology

Numerous works in aviation for the DGAC and the BEA

BEA

Data and limitations

- Flight periods extracted from the factual report
  - Period 1 month
- Repositionning flights : unknown
- activity between the flights : unknown

BEA

The Avoidance of Excessive Fatigue in Aircrew

Arab Republic of Egypt ECAR Part 121
Ministry of Civil Aviation

- **Maximum cumulative duty hours** : the average weekly total of duty hours shall not exceed **50 hours, averaged over any 4** consecutive weeks. All types of duty, flying duty, ground duty, split duty, standby and positioning shall be counted in full for this purpose
    - We don't have the information (repositioning, standby…)
- **Maximum monthly flying hours**: the maximum number of flying hours which a cockpit crew member may be permitted to undertake during any **30 consecutive days shall be 100**.
    - According to the factual documents : nearly 80 flight hours

    discrepancies between the data collected in the factual report and the FDR data

    we're unable to conclude about these points of the regulation

but

BEA

Crewmembers shall :

- Not work more than seven consecutive days between days off;
  - 20/12 to 27/12 : **8 days without days off,**
- Have 2 consecutive days off in any consecutive 14 days;
  - 18/12 to 3/01 : **16 days without 2 consecutive days off.**

BEA

Results : cpt

Duty time (last month) :

- At least 140 duty periods hours
- At least 80 flight hours
- Period of 8 consecutive days on duty (legislation 7)
- Period of 16 consecutive days on duty, with only 1 day off (legislation 14)

BEA

Arab Republic of Egypt ECAR Part 121
Ministry of Civil Aviation

- The ECAA will **conduct periodic and spot checks of operator's records** and pilot in command reports to assess whether the operator's planning of flight schedules and duty in general is producing results which are **compatible with the limitations** provided for in the operator's scheme.
  - Available report ?

BEA

Results

- No evidence of circadian disrythmia (jet lag),
- **Heavy workload** for the captain
- **Sleep deficit** due to
  - workload,
  - Planning (2 early take-off in 2 days, copi 3)
- Influence of the new year celebration (ldg 2300 the 31 december), repositioning flights ?

Crew performance and fatigue

Sleep and alertness

Recommendations guide 1998

BEA

Results : fatigue

- Physiological
  - Reduces
    - Muscular strengh
    - Binocular vision
    - Muscular coordination
  - Increases
    - Visual accomodation delay
- Psychological
  - Reduces
    - Memory
    - Ability to communicate and cooperate
    - vigilance
  - Increase
    - Irritability, anxiety
    - Lapses, Errors
    - Response time…

BEA

Conclusion:

important to take into account the **influence of the fatigue (contributive factor)** in the crew behaviour (interference with spatial desorientation, CRM…)

need to know the **exact planning** to amend the LAA study

2.6.6 Flash Air Flight 604 Perceptual Study (Contribution by NTSB)

Flash Air Flight 604 Perceptual Study

B737
NIGHT TAKE-OFF

Preliminary Findings 20 AUG 2004

Braden J. McGrath, PhD.

Aircraft data from the flight data recorder (FDR) that influences spatial orientation is currently being analyzed and evaluated at NAMRL at the request of William J. Bramble, Jr., Ph.D., Senior Human Performance Investigator, National Transportation Safety Board, Office of Aviation Safety, Human Performance Division.

Background

Spatial disorientation (SD) and subsequent loss of situation awareness (LSA) mishaps for military air forces, commercial aviation, and general aviation have an estimated annual cost in the billions of dollars. From 1999 to 2002, the US Navy experienced 36 mishaps where SD was a major causal factor. The Naval Aerospace Medical Research Laboratory (NAMRL) has developed an SD mishap analysis tool to support US Navy mishap boards in their investigations, to provide insight into the problem of SD in naval aviation, and to train aviators to avoid SD mishaps. The SD mishap analysis tool uses spatial orientation models and computer animation techniques to produce three-dimensional (3-D) computer simulations of SD mishaps.

NAMRL provides no-cost assistance to other government agencies as it allows NAMRL researchers to make improvements to the SD mishap analysis tool by gaining access to different types of mishap profiles and data not often available in Navy mishaps. In particular, NAMRL is assisting the NTSB for the Flash Air Flight 604 mishap as it allows NAMRL researchers to investigate a mishap that has low rotation rates in a 1 G environment, and access to FDR data not often available in Navy mishaps.

Method

Step 1: Using data from the flight data recorder, estimates of the 3-D angular position and velocity, and 3-D linear acceleration experienced by the pilot of the mishap aircraft are calculated using the mathematical analysis software package, MatLab™ (The MathWorks, Inc.) in a format required for the SD analysis

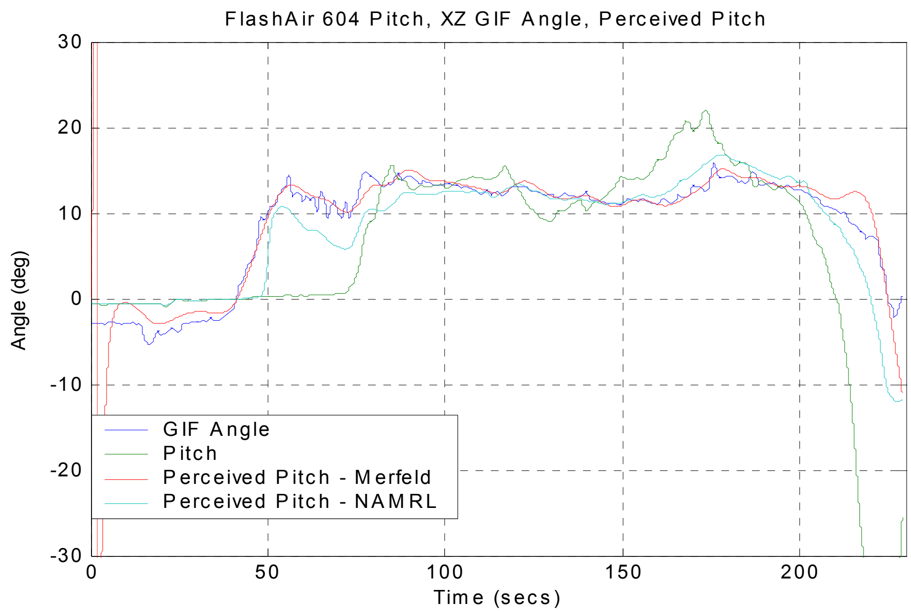
Step 2: The estimates of the 3-D angular position, angular velocity, and linear acceleration of the mishap aircraft are input into two spatial orientation models to produce an estimate of perceived pilot orientation. The SD mishap analysis tool uses both an observer theory model (Merfeld, 2001), and a classical systems model (Grissett, 1993) to estimate spatial orientation perception using the modelling analysis software package Simulink™ (The MathWorks, Inc.). Both of these spatial orientation models do not include visual or somatosensory inputs, and are based on vestibular models from current literature and additional data from centrifuge, aircraft experiments, and aircraft mishaps gathered at NAMRL over the previous 40 years. The spatial orientation models assume that the pilot is not using outside visual horizon cues, and the pilot does not look at the aircraft instruments.

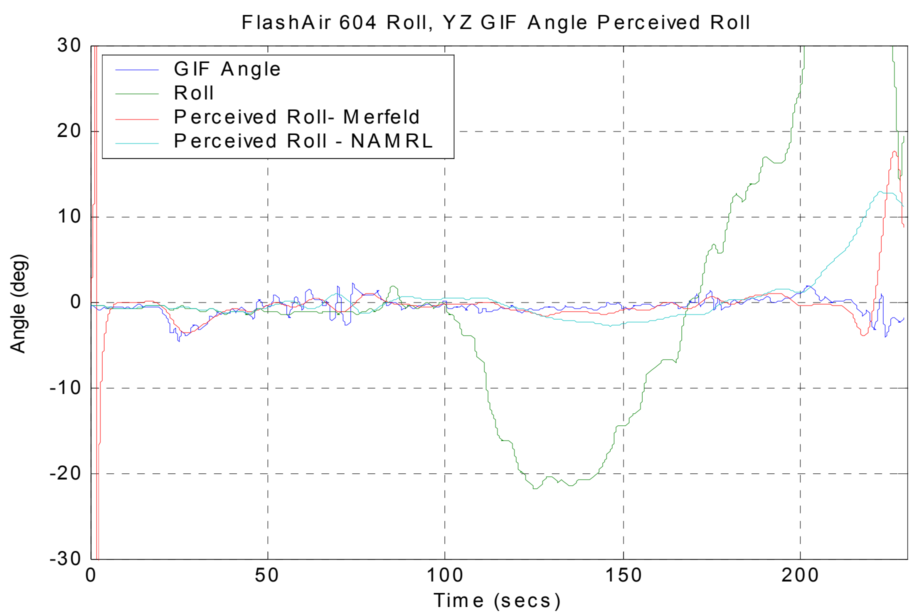
Step 3: To determine the accuracy and validity of the perceived pilot orientation, including analyses when the model results are significantly different, the perception results can be evaluated using data from other sources, including pilot control inputs, expert advice on the mission, cockpit voice recorder and eyewitness accounts. If required, the estimated perceptual results are modified to overcome the limitations of the spatial orientation models to produce a more accurate estimation of the perceived pilot orientation.

Results

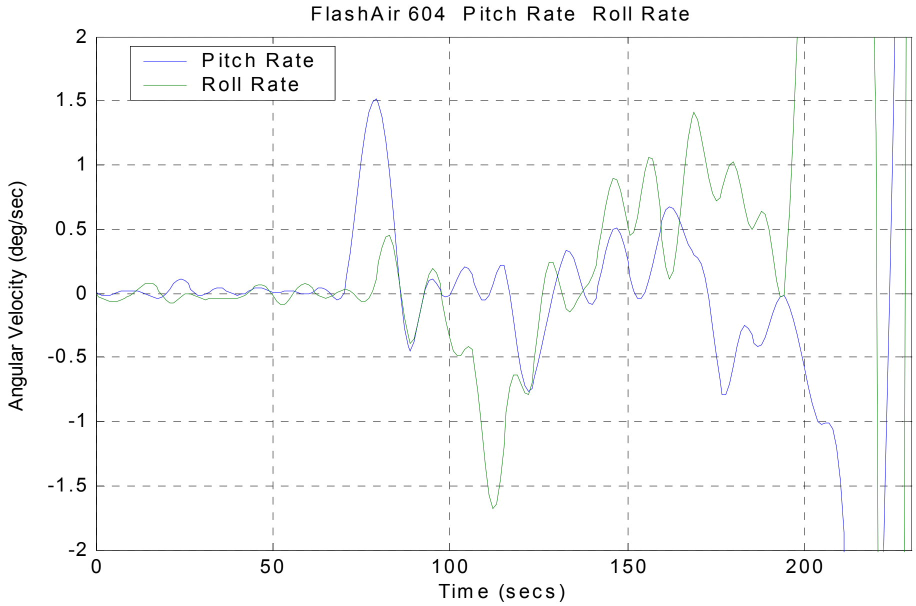
Step 1 is incomplete as the data analysis assumes pilot is situated at the FDR sensor location. If requested, NAMRL will recalculate the data using accurate pilot – sensor position data. For Step 2, both the NAMRL model (Grissett, 1993) and the Merfeld model (Merfeld, 2001) analyses are complete.

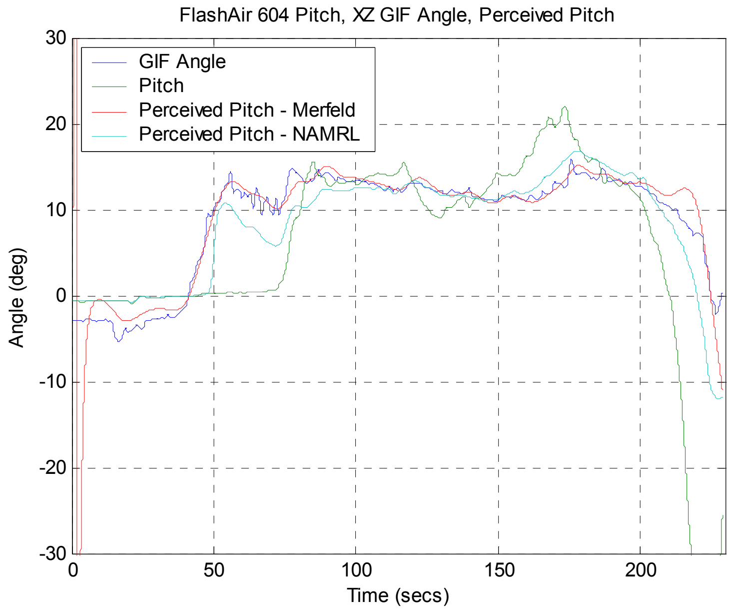
1) There is a difference between the resultant gravito-inertial vector angle and the aircraft attitude in pitch and roll. Due to this difference, both perceptual models estimate pitch and roll misperception. not been validated by additional analysis using the Merfeld or other perceptual models .

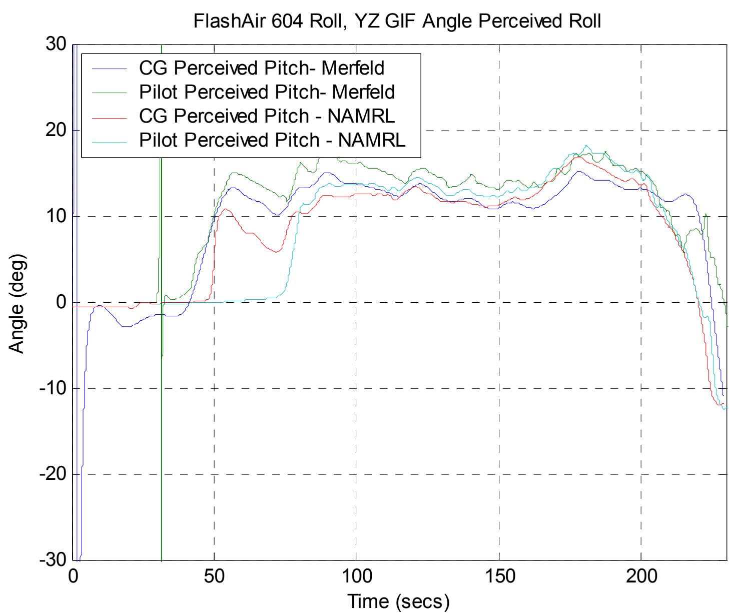


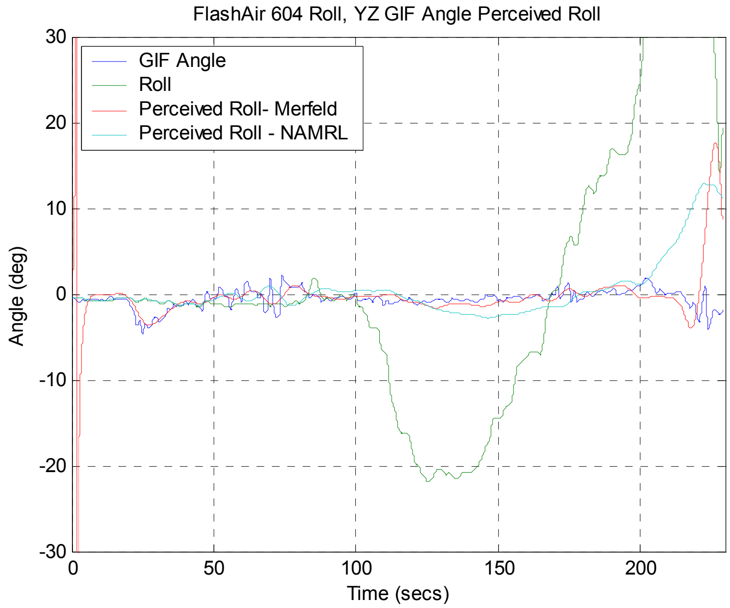


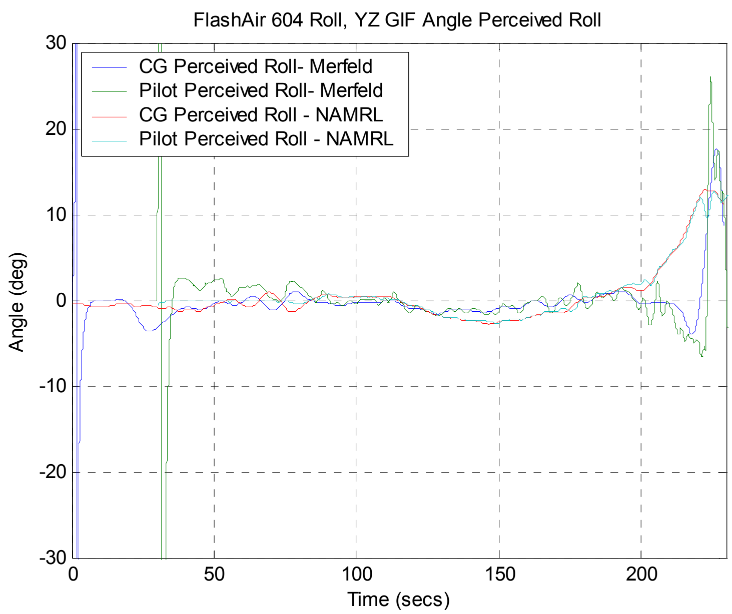
2) The angular rates are in the range of 1.0– 2.0 deg/sec. This magnitude is within the range of thresholds for detection of angular motion published in the literature. This indicates possible undetected attitude changes – especially the roll because of the resultant YZ GIF angle remains at zero. In addition to the Merfeld model, NAMRL researchers will attempt to investigate this possible sub-threshold roll input more thoroughly using additional models published in the literature.


FlashAir 604 Pitch Rate Roll Rate
Pitch Rate
Roll Rate
Angular Velocity (deg/sec)
Time (secs)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
50
100
150
200

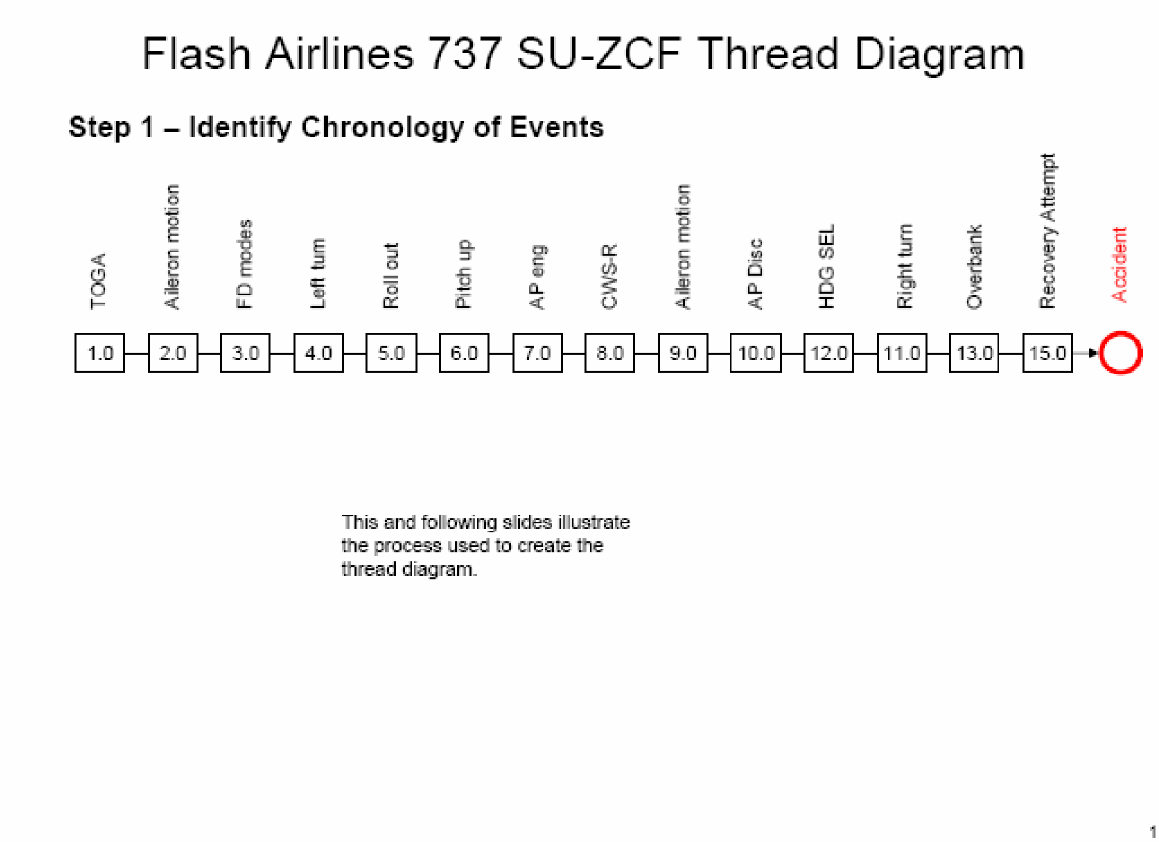

FlashAir 604 Pitch, XZ GIF Angle, Perceived Pitch
GIF Angle
Pitch
Perceived Pitch - Merfeld
Perceived Pitch - NAMRL
Angle (deg)
Time (secs)
30
20
10
0
-10
-20
-30
0
50
100
150
200


FlashAir 604 Roll, YZ GIF Angle Perceived Roll
CG Perceived Pitch- Merfeld
Pilot Perceived Pitch- Merfeld
CG Perceived Pitch - NAMRL
Pilot Perceived Pitch - NAMRL
Angle (deg)
Time (secs)
30
20
10
0
-10
-20
-30
0
50
100
150
200


FlashAir 604 Roll, YZ GIF Angle Perceived Roll
GIF Angle
Roll
Perceived Roll- Merfeld
Perceived Roll - NAMRL
Angle (deg)
Time (secs)
30
20
10
0
-10
-20
-30
0
50
100
150
200

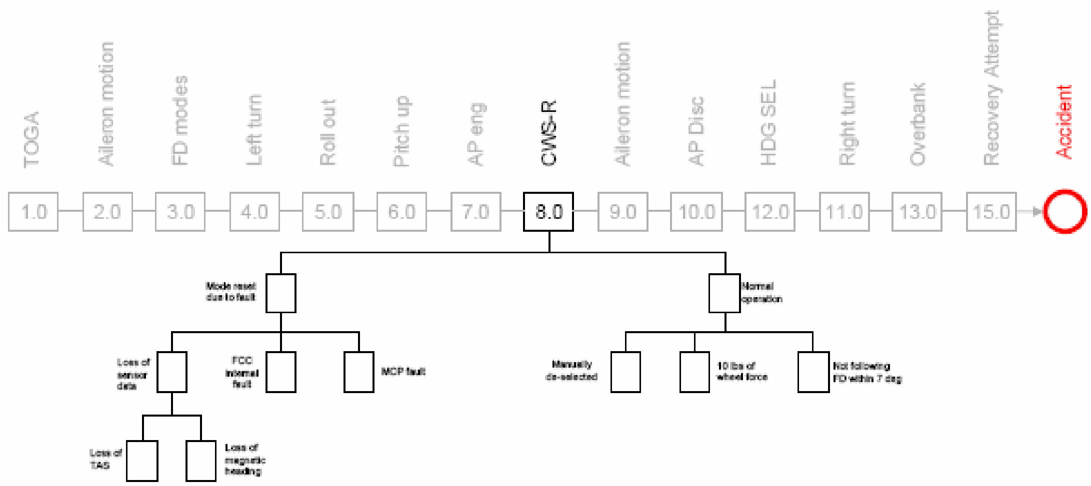

FlashAir 604 Roll, YZ GIF Angle Perceived Roll
CG Perceived Roll- Merfeld
Pilot Perceived Roll- Merfeld
CG Perceived Roll - NAMRL
Pilot Perceived Roll - NAMRL
Angle (deg)
Time (secs)
30
20
10
0
-10
-20
-30
0
50
100
150
200

2.6.7 Thread Overview Updates Cairo 26-Aug-05, Flash Air CBS Sub-group Comments (24 August 2005)"



Flash Airlines 737 SU-ZCF Scenario Tree

Step 2 – Develop candidate scenarios for each event



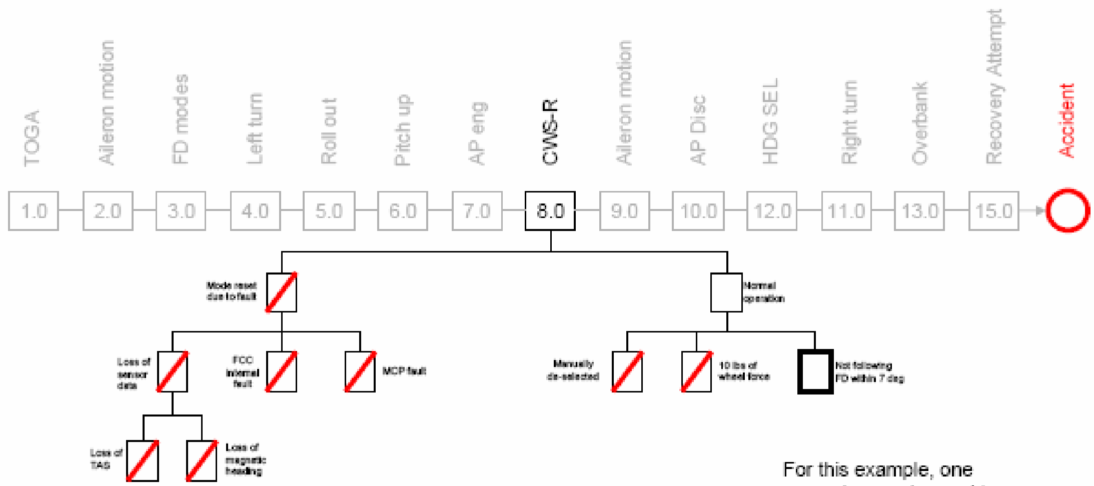
Example shows scenario tree structure for event 8.0

Similar trees were developed for each event

2

Flash Airlines 737 SU-ZCF Scenario Tree

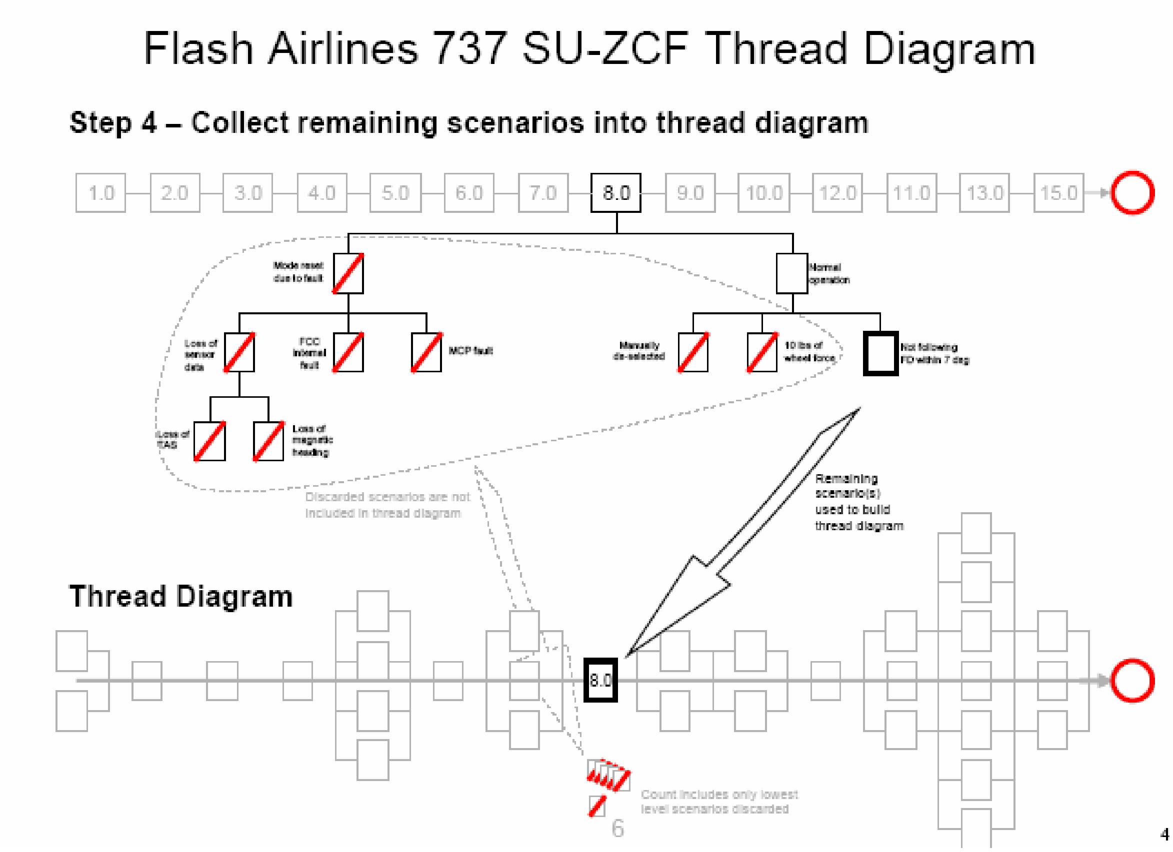
Step 3 – Rule out scenarios based on known information



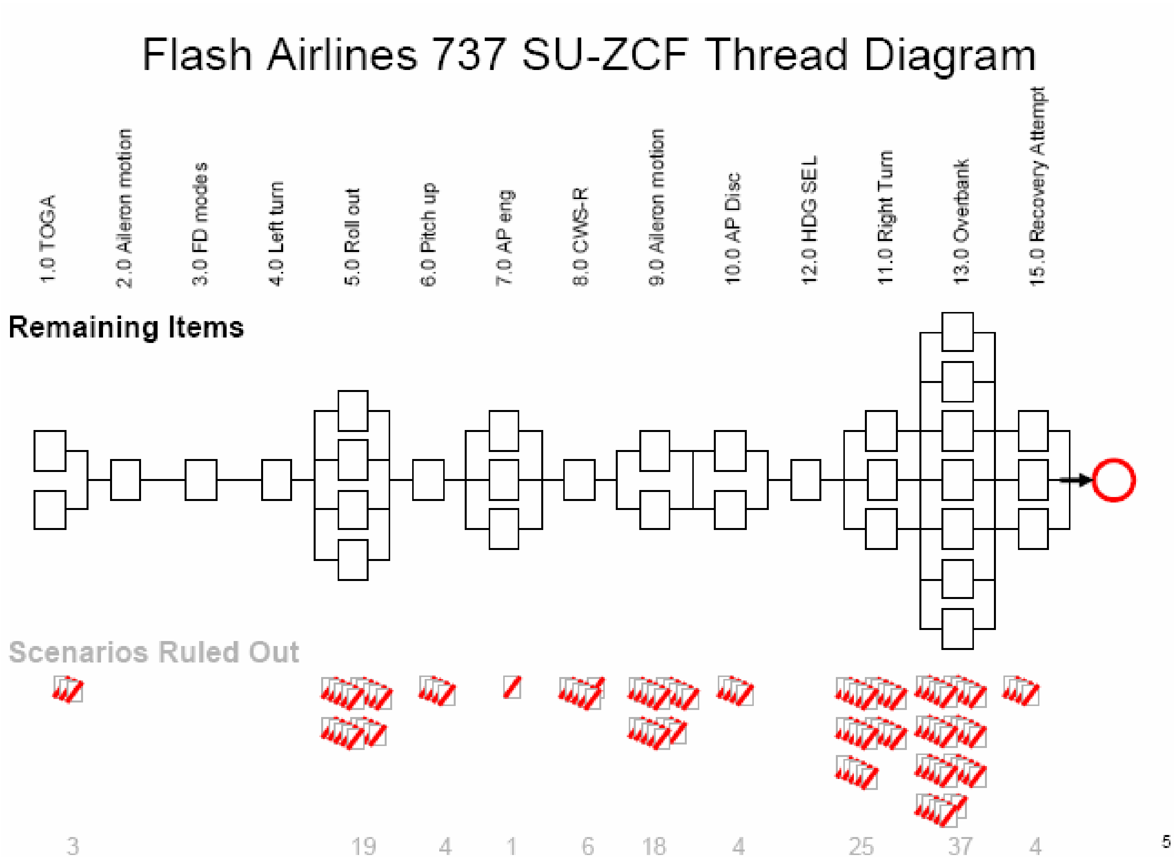
For this example, one scenario was deemed to match the data. The rest were ruled out.

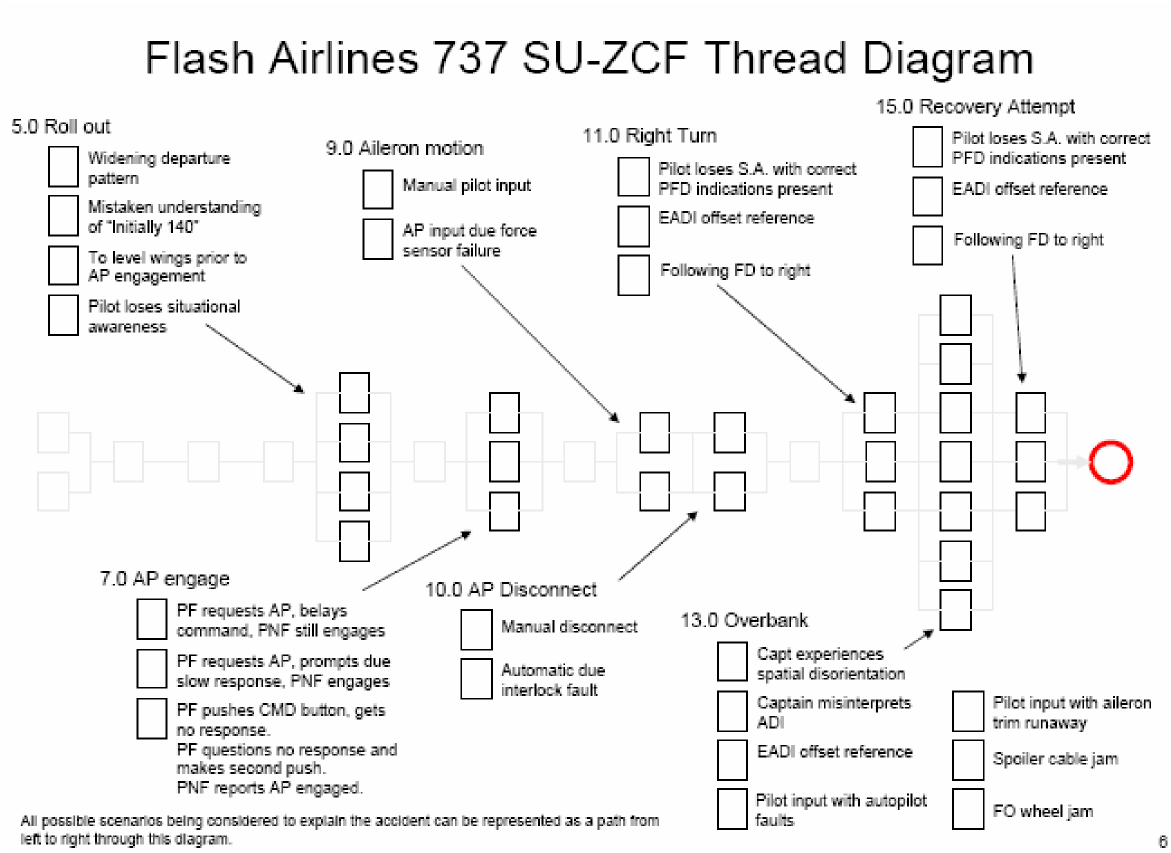
For other events, multiple scenarios remained as they could not be ruled out.

3



Flash Airlines 737 SU-ZCF Thread Diagram
Step 4 – Collect remaining scenarios into thread diagram
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
12.0
11.0
13.0
15.0
Mode reset due to fault
Normal operation
Loss of sensor data
FCC internal fault
MCP fault
Manually de-selected
10 lbs of wheel force
Not following FD within 7 deg
Loss of TAS
Loss of magnetic heading
Discarded scenarios are not included in thread diagram
Remaining scenario(s) used to build thread diagram
Thread Diagram
8.0
Count includes only lowest level scenarios discarded
6
4


Flash Airlines 737 SU-ZCF Thread Diagram
1.0 TOGA
2.0 Aileron motion
3.0 FD modes
4.0 Left turn
5.0 Roll out
6.0 Pitch up
7.0 AP eng
8.0 CWS-R
9.0 Aileron motion
10.0 AP Disc
12.0 HDG SEL
11.0 Right Turn
13.0 Overbank
15.0 Recovery Attempt
Remaining Items
Scenarios Ruled Out
3
19
4
1
6
18
4
25
37
4
5



Flash Airlines 737 SU-ZCF Thread Diagram
5.0 Roll out
Widening departure pattern
Mistaken understanding of "Initially 140"
To level wings prior to AP engagement
Pilot loses situational awareness
9.0 Aileron motion
Manual pilot input
AP input due force sensor failure
11.0 Right Turn
Pilot loses S.A. with correct PFD indications present
EADI offset reference
Following FD to right
15.0 Recovery Attempt
Pilot loses S.A. with correct PFD indications present
EADI offset reference
Following FD to right
7.0 AP engage
PF requests AP, belays command, PNF still engages
PF requests AP, prompts due slow response, PNF engages
PF pushes CMD button, gets no response.
PF questions no response and makes second push.
PNF reports AP engaged.
10.0 AP Disconnect
Manual disconnect
Automatic due interlock fault
13.0 Overbank
Capt experiences spatial disorientation
Captain misinterprets ADI
EADI offset reference
Pilot input with autopilot faults
Pilot input with aileron trim runaway
Spoiler cable jam
FO wheel jam
All possible scenarios being considered to explain the accident can be represented as a path from left to right through this diagram.
6

5.0 Roll back towards wings level

Scenario	Pros	Cons
Widening Departure Pattern p3 – G034 (Intentional control action)	Chief pilot reports some crews choose to widen their departure pattern by squaring turn at approximately 90° to runway heading. The wings level heading, 140°, is 80° from the runway heading. It has to be noticed that the crew never briefed the departure as it is usually done (headings, sets, displays,...). All the dialogues between the Capt and the FO before the turn is about "140". This match with what said Flash ex-Chief pilot in his last statement about widening pattern. The aircraft remained near heading 140 for 9 seconds. Roll rate decreases as aircraft nears 140. The observer was also a friend of the airline director of operations riding as a passenger. The PF (captain) may have wanted to ensure that he did not violate the local VOR altitude crossing practice in the presence of the director's friend. The previous day's departure from SSH included a 270 turn to right and the flight crossed the VOR below 7000 ft. The approach chart in the AIP states minimum quadrant altitude is 10,100 ft NW of VOR.	The same crew made a similar departure about 24 hours previously, at a heavier weight without widening their departure. There is no discussion about this maneuver recorded on the CVR. There is no evidence on FDR that flight director was used for this maneuver.
Mistaken understanding of "Initially 140" p3 – G035 (Intent.)	ATC clearance: "Destination Cairo as filed, climb initially flight level one four zero" FO read back "destination Cairo via flight plan route one four zero". Captain later asks for confirmation about "initially 140" from FO and for FO to confirm with ATC. After initial clearance, neither ATC nor FO specify whether "140" refers to a heading or altitude. Airplane rolls wings level on exactly 140.	No request from captain to set selected heading to 140. Did not ask for clarification of altitude clearance. "Initially" phrase refers to altitude, not heading. "14000" set in altitude window immediately after ATC clearance and was in the window during subsequent discussion and confirmation with ATC.
To level wings prior to engaging autopilot p3 – G036 (Intent.)	On FDR flight 10, the crew did not engage the AP until wings level at approximately 9000 ft following completion of a series of turns after takeoff.	On FDR flight 9, the crew engaged the autopilot in the middle of a 270° turn at a bank angle of 20 to 25°.
Pilot loses awareness of heading or bank p3 – G039 (unintent.)	Roll out coincident with passing over coastline and resulting loss of outside visual references. Pitch begins to deviated from expected value. Misleading vestibular cues were present.	Attitude information available on displays to 3 flight deck occupants.

7

7.0 AP Engagement

Scenario	Pros	Cons
PF requests AP PF cancels request PNF pushes CMD button anyway	Consistent with company practice. Impression from CVR is that the first officer is manipulating the MCP Controls prior to AP engagement. CMD button is located on right side of MCP, closer to F/O.	Boeing procedure is for PF to push the CMD button.
PF requests AP PF prompts PNF due slow response PNF pushes CMD button	Consistent with company practice. Impression from CVR is that the first officer is manipulating the MCP Controls prior to AP engagement. CMD button is located on right side of MCP, closer to F/O.	Boeing procedure is for PF to push the CMD button.
PF pushes CMD button, gets no response. PF questions no response and makes second push. PNF reports AP engaged.	Boeing procedure is for PF to push the CMD button.	According to Flash chief pilot, procedure was for PF to request AP and PNF to push the button. The Flash chief pilot acknowledged this was opposite to Boeing recommended procedure on this point. A written procedure could not be found in the available Flash Operations Manual (some pages were missing).

8

9.0 Aileron Motion (Right Roll)
(Need to revisit)

Scenario	Pros	Cons
Manual pilot input p2 – G029	Magnitude and duration of aileron motion recorded on FDR data were compared to simulated autopilot behavior if engaged and to two previous manual control motions recorded in previous 30 seconds. The motion recorded of the FDR is more similar to the previous manual inputs than to the simulated autopilot behavior. (The simulated autopilot behavior presumed normal autopilot behavior. The recorded motions are within the autopilot authority limits.) *(there was no consensus on this point)*	Amplitude and direction of aileron motion recorded on previous FDR data showed some similarities with a/p behavior. *(there was no consensus on this point)*
AP input due force sensor failure p3 - G030.1		The force sensor was known to be working properly at AP engagement, about 1.5 seconds earlier. Motion of aileron was neither abrupt and nor in one direction only, as would be expected from a force sensor fault.

9

10.0 Autopilot Disengagement

Scenario	Pros	Cons
A/P disengages due to manual disconnect p2 – G029	Warning length is consistent with "double click" typical of manual disconnects (within allowable warning duration tolerance).	No disengagement callout by crew on CVR.
A/P disengages due to interlock fault p1 – G001.1.1		Requires interlock fault in the 3 seconds since the AP successfully engaged.

10

11.0 Right Bank Begins (<20° bank)

Scenario	Pros	Cons
Capt loses situational awareness with correct PFD indications present (e.g. distraction, misinterpretation, etc) p3 – G039	Refer to CBS report.	Captain just asked for heading select and therefore was likely looking at PFD at that time.
Capt loses S.A. while following erroneous EADI offset reference p3 – G037		Fault display on EADI unusual enough to be evident to crew and unlikely to be mistaken for valid data Captain's control inputs more closely match response to perceived valid input. We know the EADI was OK. Even if it fails (it would have black screen), Stand by Horizon was supposedly functioning. We have no comment from the Capt nor from the FO nor the Observer about failures on this instrument.
Capt loses S.A. while following FD commands due to erroneous selected heading (p5 – G047) or unintended turn direction (p6 – G051, G049.1)	The captain just asked for the flight director by calling for "Heading Select" FDR data shows heading select mode engages. The pitch FD error is decreasing during this time, therefore the pilot was likely following the flight director in both pitch and roll. Accident airplane had "shortest direction" turn behavior on FD for turns >180 degrees. Simulator used for training at RAM did not behave this way – it always honored direction of turn on MCP knob.	Capt asked for Heading select. FDR data for selected heading (recorded at 64 second intervals) indicate the FD would have been commanding a left, not a right, turn.

11

13.0 Overbank (1 of 2)

Scenario	Pros	Cons
Capt experiences spatial disorientation (Type II)	Refer to CBS report.	
Capt misinterprets ADI indications	Refer to CBS report.	
Following erroneous EADI – offset airplane reference p7 – G094		This fault may have served to confuse the captain, but two other sources of attitude information would be available. The fault would not likely have led to a drastic change in the pilot inputs, as is evidenced by the change from <1°/sec to >3 °/sec roll when the FO announces "turning right".
Pilot input in the presence of autopilot actuator hardover due to intermittent triple faults p11 – G055, G056, G057)	Refer to CBS report regarding CVR comments.	Requires multiple faults to occur simultaneously. Failures could affect the aircraft trajectory. Demonstrated in the M-Cab that all the faults except the quintuple fault (i.e. 80 lbs on the wheel) were easily recoverable.

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13.0 Overbank (2 of 2)

Scenario	Pros	Cons
Pilot input in the presence of aileron trim runaway a) Full p20 – G043 b) Partial p20-G044	Refer to CBS report regarding CVR comments.	Requires two faults to occur simultaneously (one of which may be latent) or manual activation. Trim could affect the aircraft trajectory unless additional wheel forces are applied to counter the trim. Demonstrated in the M-Cab to be easily recoverable.
Scenario 10 (Spoiler wing cable jam) in at time 92450 and clears at 92472	MCA requests simulation be redone at point on maximum wheel deflection.	MCA requests simulation be redone at point on maximum wheel deflection. Recorded wheel deflection requires maximum of ~ 60 lbs which may result in an audible change in voice. Recorded aileron position indicates wheel was moved smoothly through the point of ~60 lbs force increase on multiple occasion. Voice effects and smoothness of control require further study.
Scenario 10a (F/O wheel jam) in at time 92450 and clears at 92472	MCA requests simulation be redone at point on maximum wheel deflection.	MCA requests simulation be redone at point on maximum wheel deflection. Recorded wheel deflection requires maximum of ~ 60 lbs which may result in an audible change in voice. Recorded aileron position indicates wheel was moved smoothly through the point of ~60 lbs force increase on multiple occasion. Voice effects and smoothness of control require further study.

13

15.0 Recovery Attempt

Scenario	Pros	Cons
Capt Input Only p1 - G009	Captain was the pilot flying with nothing on CVR to suggest that control was transferred.	Refer to CBS report regarding CVR comments.
FO Input Only p1 - G011	Refer to CBS report regarding CVR comments.	FO does not announce he is taking control.
Joint Attempt	Previous upset events have resulted in multiple crew making control inputs.	FO does not announce he is taking control.

14

The study performed by a team of qualified Human Performance Specialists have come up with findings summarized as follows:

- *An event starting from the time of call for autopilot engagement through the time of the captain statement “see what the aircraft did” caused obvious crew distraction. This distraction may have developed to Spatial Disorientation (SD) to the captain until the time the F/O announced “A/C turning right “ and acknowledged by the captain.*

- *There are conflicting signals in the following period of time (~ 17 seconds), it is unclear whether the captain remained in SD or was the crew unable to perceive the cause that was creating an upset condition until the time when the F/O announced that there was no A/P in action.*

  After the time when the F/O announced “no A/P commander” the crew behavior suggests that recovery attempts were consistent with expected crew reaction, evidences show that the gravity of the upset condition with regards to attitude, altitude and speed made this attempt insufficient to achieve a successful recovery.