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Group Chairman's Factual Report - Flight Data Recorder

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(7 pages)

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C.

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Group Chairman's Factual Report - Flight Data Recorder

A. ACCIDENT DCA-97-MA-058

Location	:	Agana International Airport, Guam
Date	:	August 5, 1997
Time	:	0142 Local Time (1542 Coordinated Universal Time)
Aircraft	:	Korean Air Lines Flight 801, a Boeing B-747-300, HL-7468

B. GROUP IDENTIFICATION

Chairman	:	Thomas R. Jacky, NTSB
Member	:	Sumio Thomas Sakata, Boeing Commercial Airplane Group
Member	:	George Kaseote, Federal Aviation Administration (FAA)
Member	:	Heung Ok Choi, Korean Ministry of Construction & Transportation
Member	:	Kim Yung Yook, Korean Air
Member	:	Joseph Poirier, Pratt & Whitney

C. SUMMARY

The flight data recorder (FDR), a Sundstrand Data Corporation (SDC) Digital Flight Data Recorder model 573A, S/N 2663, was removed from HL-7468 after the accident. The FDR was sent to the Vehicle Performance Division's laboratory in Washington, D.C. for readout and evaluation.

Readout of the FDR was accomplished using the laboratory's playback hardware. Readout was accomplished without significant data loss throughout transcription of the accident flight until approximately 3 seconds prior to transition to the oldest data. For the final 5 minutes of the accident flight transcription, in the areas of sync (and subsequent data) loss occurrences, techniques were used to recover data, so that a composite data set of the accident flight resulted. Data plots and tabular listings of pertinent data were then prepared and included in this report.

Transcription of the accident flight and observation of the resultant data determined in the following points:

1) The accident flight, as transcribed, was approximately 3 hours and 48 minutes in duration from liftoff to the loss of data. The transcription file used for this report represented approximately 4 hours and 52 minutes in duration. The transcription file included the approach and landing of the leg immediately prior to the accident flight, as well as data following the transition to 25 hour old data.

2) Portions of two consecutive subframes (where 1 subframe equals 1 second) of data were lost due to synchronization loss at time 17,338 and 17,339 seconds elapsed time, approximately 2 seconds prior to the transition to oldest data. The transition from newest data to oldest (i.e., 25-hour old) data occurred during subframe 17,341. The final subframe to be written in its entirety, without loss of data, was subframe 17,340.

3) The magnetic heading values during the accident takeoff roll were about 322°. After takeoff, the aircraft heading for most of the accident flight, until the final approach and descent, was between 135° and 180° magnetic.

4) Following the accident flight takeoff, the airplane's climb was arrested at about 37,000 feet pressure altitude, about 19 minutes after takeoff. The airplane then maintained 37,000 feet for about 52 minutes, then initiated a climb to about 41,000 feet pressure altitude, arrested approximately 4:30 minutes later. The 41,000 feet pressure altitude values were maintained for 2 hours and 3 minutes, some 3 hours and 20 minutes after liftoff, when the aircraft initiated a descent.

5) The final valid recorded altitude value was 636.3 Feet pressure altitude. The altitude values had consistently decreased from approximately 2700 Feet at time 17,203 seconds elapsed time, where the data had last remained constant, some 140 seconds prior to the loss of data.

6) Pitch attitude data were consistently about zero for the last approximately 30 seconds of data, until time 17,336 seconds, when the pitch attitude increased, from +1.41° aircraft nose up (ANU), until the last valid recorded data, at 17,340 seconds, of +8.09° ANU.

7) The airplane's FDR system recorded Engine Pressure Ratio (EPR) data for each engine once per frame, i.e., once every 4 seconds for any one engine. For most of the final 5 minutes of recorded data, the recorded EPR values of all four engines were nominally 1.00. Variations from this nominal EPR were consistent across all four engines. However, at time 17,290 seconds, each engine's recorded EPR values momentarily increased above 1.00, to about 1.10, then stabilized to about 1.04. The EPR values began increasing, from engine number 2's 1.066 EPR at 17,333 seconds, to a maximum recorded value of 1.346, recorded as an engine number 3 value, at 17,338 seconds. The final valid recorded value was recorded at time 17,340 seconds, an engine 1 value of 1.006 EPR.

8) Based on the manufacturer’s documentation, the Trailing Edge Right Inboard surface position was the only trailing edge flap position recorded by the airplane’s FDR system. At time 17,108 seconds the trailing edge, right inboard flap position data values increased from about 5° to approximately 10°. At time 17,264 seconds, the trailing edge right inboard position values increased from 10° to 20°, and then to 30°. The values remained consistent, at approximately 30°, for 72 seconds, until time 17,336 seconds, when the values decreased until the final valid recorded value, at time 17,338 seconds, of 25.42 °.

The reader is cautioned that the trailing edge, right inboard flap position represents the trailing edge flap position as associated with the cockpit flap lever, and therefore the values may not be exactly 5, 10, 20, 25, or 30 degrees.

9) The horizontal stabilizer (pitch trim) position was approximately 6 units five minutes prior to the data transition. At time 17,142 seconds, the horizontal stabilizer position values increased to 6.6 units, and at time 17,248 seconds, the values increased to 7.88 units. The final, valid recorded value, 8.01 units, was recorded at 17,340 seconds.

D. DETAILS OF INVESTIGATION

1. Description of Recorded Data

This model FDR records airplane flight information in a digital format onto four tracks of a 1/4-inch vicalloy tape. The FDR records 64 words of digital information every second, with each word 12 bits in length. Each grouping of 64 words (each second) is called a subframe. Each subframe has a unique 12-bit synchronization (sync) word identifying it as either subframe 1, 2, 3, or 4. The sync word is the first word in each subframe. Each grouping of consecutive 1, 2, 3, and 4 subframes comprise a frame (i.e., four seconds of data). The data stream is "in sync" when successive sync words appear at the proper 64-word intervals. Each data parameter (e.g. altitude, heading, airspeed) has a specifically assigned word number within the subframe.

If the data stream is interrupted, the sync words will not appear at the proper interval or sequence and sync will be lost along with the surrounding data. A loss of data synchronization can result from either a mechanical or electrical interruption of the data. A mechanical interruption can be caused by foreign matter coming between the tape recording medium and the heads during the record or playback process. Mechanical interruptions can also be caused by recorder vibration, which can introduce wow (i.e. short-term speed variations of the recording media) and/or flutter to the tape and tape transport and distort the recorded signal. An interruption of electrical power to the recorder will also interrupt the serial data stream and cause a loss of sync. Finally, an interruption of the serial data stream to the FDR will also cause a loss of synchronization.

A document with information for converting the recorded information from binary to engineering units was provided by the airplane manufacturer, and a listing of the parameters was provided by the airline. The airlines' FDR list indicated recorded parameters in addition to those documented by the manufacturer's list. However, an extensive examination of raw data indicated that only the parameters indicated by the manufacturer's list were recorded. A listing of the parameters determined to be recorded by the FDR is included in Attachment 1.

Pressure altitude was derived by an algorithm that combines altitude coarse (sampled once per frame) and altitude fine (sampled once per subframe). The algorithm combines each subframe's fine altitude value with the closest 5,000 foot increment of the current frame's altitude coarse value, determined by subtracting the modulus of the altitude coarse value and 5,000 feet from the altitude coarse value. When the airplane's pressure altitude is less than 5,000 feet, the altitude coarse value is ignored, and the resultant pressure altitude value is equivalent to the altitude fine value.

The FDR's recording medium is required to retain the airplane's most recent 25 hours of operation. This is accomplished by erasing the oldest data and replacing it with the newest. The FDR records onto 4 individual tracks, written bi-directionally. The FDR records approximately 6.25 hours of data on a track until reaching end-of-tape sensors, then reverses tape direction, increments the recording track, and writes data in the reverse direction on the tape. Using this method, the FDR records tracks 1 and 3 in one direction, tracks 2 and 4 in the opposite direction.

2. Examination and Readout

A. Examination

The FDR was sent to the Vehicle Performance Division's laboratory in Washington, D.C. after removal from the accident airplane. Upon receipt, the recorder was opened and examined for damage. The FDR's dust cover exhibited slight impact damage, but not enough to prevent the dust cover's removal from the unit. The FDR's internal electronic components and tape transport exhibited no indication of damage or excessive wear. After opening the FDR's tape protective enclosure, the position of the tape and reels were noted for reference.

An ohm-meter was then used to determine the recording track at the time of power removal. This was accomplished by measuring the resistance between the E13, E14, E15, and E16 test points on the FDR's control electronics board to determine which of the FDR's four track relays were closed. The results indicated the FDR was recording on track 1. After noting the position of the tape and tape transport, the tape platform's top tape reel was removed from the recorder's tape assembly platform and the tape medium then wound onto an empty 5½ inch tape reel in preparation for readout.

B. Readout

The tape was placed onto the Safety Board's Lockheed Raw Tape Transport (RTT) tape playback platform. The tape was positioned to the reference position noted upon opening the tape protective enclosure, and each of the tape's 4 tracks were searched for data consistent with the accident sequence followed by a transition from newest to oldest data. Once the data transition was discovered (on track 1 of 4), the entire accident flight was transcribed into a computer file.

The tape was also placed onto the Safety Board’s NAGRA tape player. The tape was again positioned to the reference position noted upon opening the tape protective enclosure, and track 1 transcribed around the data transition location. Transcription results from the RTT and the NAGRA were combined to produce a merged, composite transcription file.

The transcribed data were reduced from the recorded binary decimal values (0 to 4095) to engineering units (e.g., feet, knots, degrees, etc.) by conversion formulas obtained from the airplane manufacturer. The actual conversion is accomplished by an automated process that incorporates the laboratory's computer and associated software. Elapsed time, or DFDR Subframe Reference Number, from the beginning of the data transcription was used as the time base for data output. The FDR did not record an independent time source (e.g., Coordinated Universal Time (UTC), or Greenwich Mean Time (GMT)) nor a frame counter to provide timing information.

Inspection of the transcribed data revealed the recorder operated normally, except for a loss of synchronization approximately 3 seconds prior to the data transition to 25-hour old data. A technique known as BITDUMP was employed in an effort to recover the out-of-sync data. The process allows the transfer of a continuous stream of data bits from the tape medium directly to computer memory, regardless of sync. When the BITDUMP hardware is enabled data transfer begins once a subframe “1” sync word is recognized and continues until 120,000 bits have been stored.

BITDUMP software routines were used to produce listings in 12-bit octal format of the stored data, plus a table of bit shift values required for proper sync word alignment. Software routines were then used to shift the out-of-sync subframe data to achieve proper sync word alignment and create a file of the corrected data frame. The corrected frame was then combined with the in-sync data to from a composite file. Normal data reduction techniques were then used to convert the composite data to engineering units and discrete values.

The first appreciable loss of data during the final five minutes of the accident flight occurred during elapsed time 17,338 seconds, a number "3" subframe. Observation of the recorded parameters, subframe sync codes, and BITDUMP results indicated that, in addition to the portion of the subframe at 17,338 seconds, a portion of the next sequential subframe (i.e., 17,339 seconds, a number “4” subframe) of data was also lost. The next sequential subframe, at time 17,340 seconds, was recovered in its entirety. The transition to 25-hours old data began in the next subframe, at time 17,341, therefore, only a portion of that number “2” subframe was recovered.

The altitude coarse value at time 17,252 seconds was recorded at a value of 8,408.7 feet, and consequently, the pressure altitude values for the related frame, times 17,252 to 17,255 were also incorrect. However, since the previous and subsequent altitude coarse values were all about 2,000 feet, the assumption was made that the altitude coarse value at 17,252 was erroneous. In addition, the pressure altitude values during the frame at 17,252 were recalculated and edited to reflect the ignored altitude coarse value.

Observation of the transcribed rudder pedal position data throughout the entirety of the transcribed data (i.e. 25 hours) revealed numerous erroneous and/or nonsensical data. No attempt was made to determine the source of this error.

3. Data Printout and Graphs

Tabular printouts of selected parameters for the final, approximate 5 minutes of recorded data, from 17,048 to 17,352 FDR Subframe Reference Number (Elapsed Time), are included in Attachment 2. Due to a limited amount of parameter space per page, the data are presented in 3 data files. However, data in different files may be aligned by use of DFDR Subframe Reference Number. Data determined to be erroneous, out-of-sync, or suspect have been crossed out and should be ignored.

Six plots of selected parameters during the accident sequence are included in Attachment 3. Plots 3-1 through 3-3 cover the final 5 minutes of recorded data, from 17,050 (4:44:10) to 17,350 (4:49:10) Elapsed Time (FDR Subframe Reference Number). Plots 3-4 through 3-6 cover the final 30 seconds of recorded data, from 17,312 (4:48:32) to 17,342 (4:49:02) Elapsed Time. Care should be used while reading the plot, as erroneous and/or out-of-sync data were not plotted.

Since, for the portion of flight presented in the tabular data files and plots, the pressure altitude of the airplane was less than 5,000 feet, pressure altitude and altitude fine may be used interchangeably as the airplane’s altitude.

In addition to the above provided data detailed above, a copy of raw, octal for the entire 25 hours contents of the FDR was made for the group representative for the Korean Ministry of Construction and Transportation. The copy was made using the Safety Board's RTT platform. The copy of the data was provided in a compressed format on 3.5 inch computer floppy diskettes.

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Tom Jacky
Aercspace Engineer

Attachments

1. HG-7468 FDR Parameter List **(Exhibit 10C)**
2. Tabular Listings of Korean Air Flight 801 FDR Data
3. Plots of Korean Air Flight 801 FDR Data **(Exhibit 10E)**