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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Flight Data Recorder Group Chairman's Solid State Flight Data Recorder Factual Report

(12 Pages)

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

September 30, 2002

Flight Data Recorder Group Chairman's Solid State Flight Data Recorder Factual Report

A. EVENT

NTSB #: DCA02MA001
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 0916 Eastern Standard Time (EST)
Aircraft: Airbus Industrie A300-600, registration: N14053

B. FLIGHT DATA RECORDER GROUP

Chairman: Cassandra Johnson, National Transportation Safety Board (NTSB)
Member: Yves Le Biannic, Airbus Industrie
Member: Ron Stefanik, Allied Pilots Association (APA)
Member: Maurice Ingle, American Airlines (AAL)
Member: Jérôme Bauer, Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA)
Member: TR Proven, Federal Aviation Administration (FAA)
Member: Ken Wolski, GE Aircraft Engines (GEAE)

The group convened at NTSB headquarters in Washington, D.C. on November 15 and 16, 2001 for readout of the solid state Flight Data Recorder (FDR). Group activities included decoding and verifying the FDR parameters recorded.

C. SUMMARY

On November 12, 2001, about 0916 Eastern Standard Time (EST), American Airlines flight 587, an Airbus A300-600, was destroyed when it crashed into a residential area of Belle Harbor, New York, shortly after takeoff from the John F. Kennedy International Airport (JFK), Jamaica, New York. Two pilots, 7 flight attendants, 251 passengers, and 5 persons on the ground were fatally injured. Visual meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the flight destined for Santo

Domingo, Dominican Republic. The scheduled passenger flight was conducted under 14 CFR Part 121.

The solid state flight data recorder (FDR), Fairchild model FA2100 (part number 2100-4042-00 and serial number 1186) manufactured by L-3 Communications, was removed from the main wreckage and sent to the National Transportation Safety Board's laboratory in Washington, D.C. for readout and evaluation.

All 81.63 hours[1] of recorded data were successfully downloaded with the final FDR data[2] recorded at 9:16:01.23[3]. During the takeoff rotation of the accident flight, the FDR parameter "Right Main Landing Gear Squat Switch" discrete transitioned from "Ground" to "Air" at 9:14:28.45, hence, the accident flight FDR data was approximately 1 minute and 32.8 seconds in duration.

Attachment I lists all data parameters recorded on the FDR. Selected FDR parameters recorded during the accident flight are presented in Attachment II in graphical format (8 plots total). Attachment III[4] contains all the data graphed in Attachment II in comma delimited (CSV) format files.

In addition to the FDR data graphed in Attachment II, there are 4 other FDR parameters that are included in this report but are not graphed. The FDR parameters "Greenwich Mean Time (GMT)[5] hours", "GMT minutes" and "GMT seconds" data are provided in Attachment III in comma delimited (CSV) format file. Lastly, the FDR "Gross Weight" data are provided in Part D Section III of this report.

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[1] Duration of FDR recording was measured in Subframe Reference Number (SRN), where each SRN equals 1 elapsed second.
[2] The FDR data stopped recording prior to impact.
[3] The FDR SRN times were correlated to the Air Traffic Control (ATC) time (also known as local time). All times, unless otherwise noted, are local time in hours, minutes and seconds (HH:MM:SS). Refer to Part D Section IV for details on the time correlation between the FDR SRN time and the ATC time.
[4] For this accident, Attachment III only exists as electronic files in the docket.
[5] The FDR GMT parameters are from the Captain's clock.

D. DETAILS OF THE INVESTIGATION

Section I – Description of Data

The Hamilton Digital Flight Data Acquisition Unit (DFDAU) (part number 775110-21-006) retrieves Aeronautical Radio, Inc. (ARINC) 429[6] format data and analog data from various sources in the airplane. The DFDAU then converts and conditions these data into a serial data stream as defined by ARINC 573/717. Next, the FA2100 FDR records the serial data stream in a digital format using solid-state Flash Memory, which is stored in a crash survivable memory unit (figure 1 illustrates a typical undamaged FA2100). Specifically, the FDR records 64 words of digital information every second, with each word 12-bits in length. Each grouping of 64 words (1 second) is called a subframe. The first word in the subframe is a unique 12-bit synchronization (sync) word identifying it as either subframe 1, 2, 3, or 4. Each grouping of consecutive subframes 1, 2, 3, and 4 comprise a frame (e.g. four seconds of data). The data stream is "in sync" when successive sync words appear at the proper 64-word intervals. The duration of FDR recording is measured in Subframe Reference Number (SRN), where each SRN equals 1 elapsed second. Each data parameter (e.g. altitude, heading, airspeed) has a specifically assigned word number within the subframe. Attachment I contains the list of parameters and the associated word assignment.

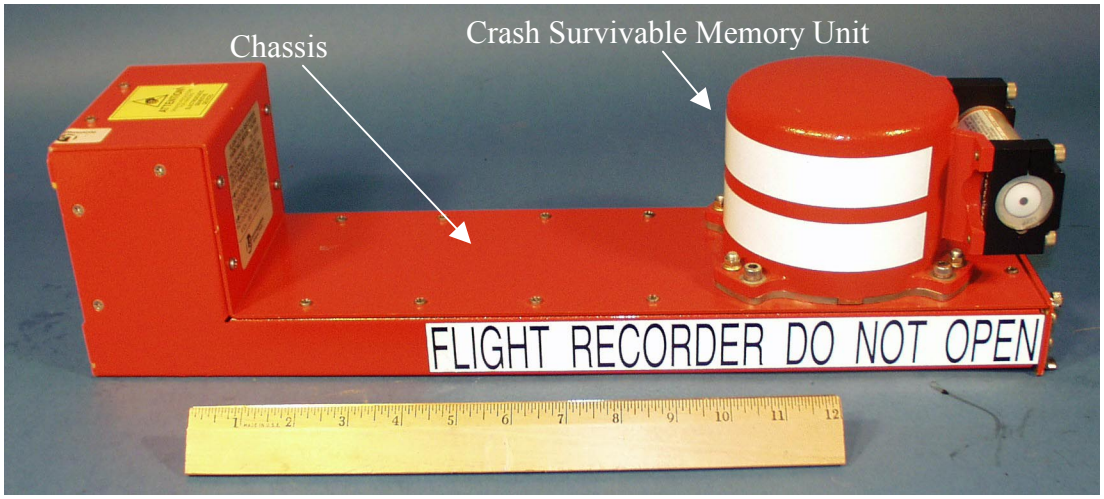

Figure 1: Example of an Undamaged FA2100 Solid State Flight Data Recorder

[6] ARINC 429 uses a unidirectional data bus standard known as Mark 33 Digital Information Transfer System (DITS). ARINC data words are always 32 bits and typically include five primary fields, namely Parity, Sign/Status Matrix (SSM), Data, Source/Destination Identifier (SDI), and Label.

Section II – Examination of Recorder

The flight data recorder showed extensive fire and impact damage (see Figure 2). The crash survivable memory unit was opened and the memory module was removed. The memory module showed no sign of damage (see Figure 3).

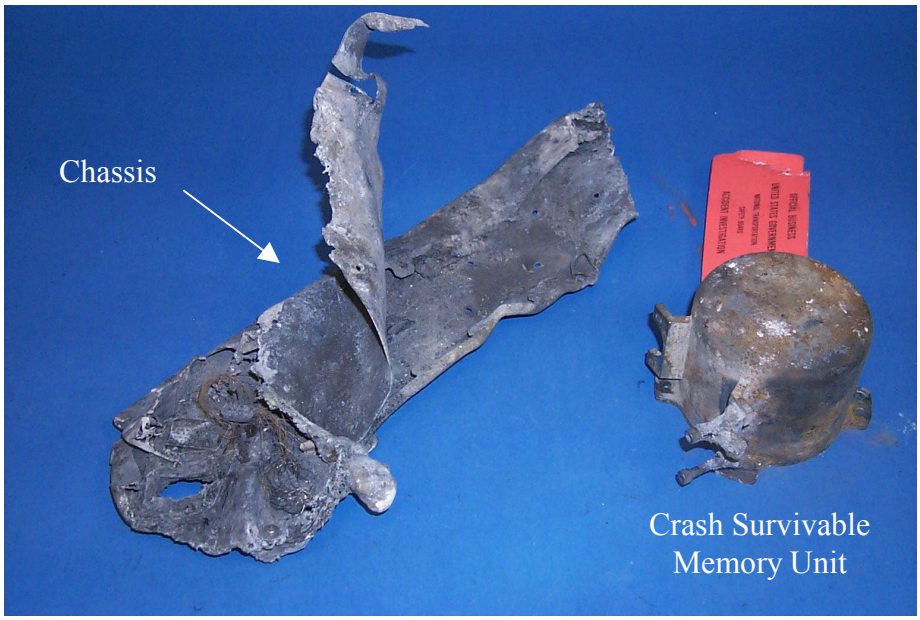

Figure 2: Recovered Solid State Flight Data Recorder

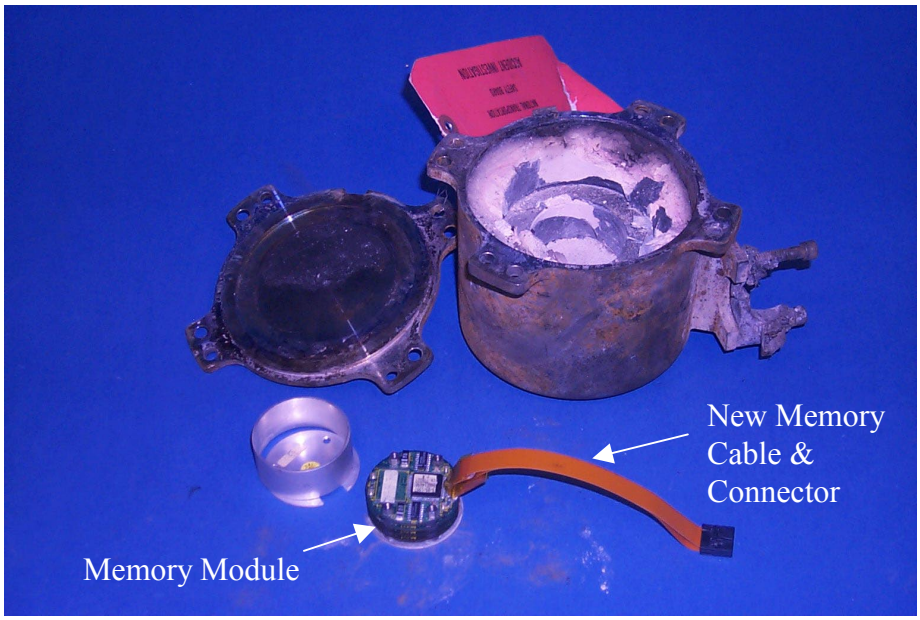

Figure 3: Crash Survivable Memory Unit Opened

Section III – Readout & Evaluation

The damaged memory cable was replaced with a new cable as shown in figure 3. The memory module was attached to the Safety Board's laboratory's investigative FDR, which was configured to emulate the accident FDR. The downloaded data were then converted from the recorded binary values (0's and 1's) to engineering units (EU) (e.g. feet, knots, degrees, etc.) using the FDR system documentation supplied by American Airlines. The actual conversion is accomplished by a process that incorporates the National Transportation Safety Board's computers and associated software.

Last Recorded FDR Data

The last recorded FDR data was evaluated using L-3 Communication's FA2100 stand-alone software. The last recorded synchronized and correlated data was recorded at 9:16:01.23. Following this data was a "Data Interruption Marker" which was inserted into the memory to indicate that the recorder stopped receiving data from the DFDAU. Within 4 seconds[7], the recorder received less than a second of unsynchronized[8] data followed by another "Data Interruption Marker". Safety Board staff attempted to decode the unsynchronized data but was unsuccessful.

During the end of the recording, the recorder did not record a "Power Up Marker" which would indicate when power[9] had been applied to the recorder. Therefore, it can be assumed that the recorder was powered until after the last "Data Interruption Marker". Also, because the recorder recorded the last "Data Interruption Marker", it can be assumed that the recorder stopped receiving data before it lost power. Lastly, since a "Timing Marker" was not recorded after the last "Data Interruption Marker", it can be assumed that the recorder lost power within 4 seconds of the last "Data Interruption Marker".

[7] The recorder would record a "Timing Marker" if 4 seconds had elapsed without receiving data. Therefore, since a "Timing Marker" was not recorded, it was assumed that the next set of data was recorded within 4 seconds.
[8] No sync code was recorded.
[9] The FDR is powered from the 115V AC Essential Bus.

"Pressure Altitude"

The FDR records "Pressure Altitude" which is based on a standard altimeter setting of 29.92 inches of mercury (in Hg). Therefore, the "Pressure Altitude" FDR data presented in the FDR plots and in the electronic data have not been corrected for the local altimeter setting at the time of the accident.

Flight Control Crew Input Position Parameters

The accident aircraft was not originally fitted with flight control crew input sensors (rudder pedal position, control wheel position and control column position)[10], which were not mandatory at the time of manufacture. American Airlines added flight control input sensors and the associated hardware to the accident aircraft using Supplemental Type Certificate (STC) number ST01999AT[11]. The flight control input sensors provide analog signals directly to the DFDAU.

During the initial readout of the FDR, it was determined that the conversion equation supplied by American Airlines for the "Rudder Pedal Position" FDR parameter was not correct. Therefore, it was necessary to examine the 81.6 hours of recorded data to obtain reference data to establish the proper EU conversion equation for the "Rudder Pedal Position". Consequently, separate EU conversion equations for both the "Control Wheel Position" and the "Control Column Position" were established.

All pre-flight control checks were identified and examined for the maximum, minimum and average-neutral raw decimal values for each flight control input parameter. The maximum and minimum values recorded by the FDR pre-flight control checks are assumed to reflect the full travel of the control input. Given that the sampling rate of the control inputs are only 2 samples per second, the peak values may have been missed. The average-neutral value was calculated when the control surface was in the "0" or null position.

[10] By no later than August 20, 2001, the FDR on the accident aircraft was required to record the control input positions as defined in the Code of Federal Regulations title 14, part 121, section 344 (14 CFR 121.344).

[11] The Supplemental Type Certificate (STC) number ST01999AT defined the installation of adding three recording parameters (control wheel position, control column position and rudder pedal position) to the existing A300 FDR to meet the requirements as defined in 14 CFR 121.344.

"Rudder Pedal Position"

The "Rudder Pedal Position" EU conversion was established from the 23 separate pre-flight rudder pedal checks retained on the FDR recording. The maximum, minimum and average-neutral raw decimal "Rudder Pedal Position" values recorded were found to be:

	FDR "Rudder Pedal Position" (raw decimal counts)	Aircraft Rudder Pedal Position[12] (degrees)
Minimum	978	-21
Average-Neutral	2139	0
Maximum	3489	21

Three separate rudder pedal ground tests[13] were performed in an effort to further establish a valid EU conversion algorithm for the "Rudder Pedal Position" parameter. These tests established the linearity of the rudder pedal position sensor. Therefore, a look-up table, which used linearity between the above-defined values, was used to convert the raw recorded "Rudder Pedal Position" FDR values into EU.

"Control Wheel Position"

The "Control Wheel Position" EU conversion was established from the 24 separate pre-flight control wheel checks retained on the FDR recording. Since the control wheel sensor is the same type sensor as the rudder pedal sensor and had a similar installation as the rudder pedal sensor, it was assumed that the control wheel sensor behaved linearly. Therefore, the following look-up table, which used linearity between data points, was used to convert the raw recorded "Control Wheel Position" FDR values into EU:

	FDR "Control Wheel Position" (raw decimal counts)	Aircraft Control Wheel Position[14] (degrees)
Minimum	1731	78.5
Average-Neutral	2115	0
Maximum	2471	-78.5

[12] The rudder pedal moves 21 degrees right rudder pedal deflection to 21 degrees left rudder pedal deflection.
[13] Three separate rudder pedal ground tests were performed on the same make and model aircraft as the accident aircraft along with the same rudder pedal sensor STC installation. Refer to the Rudder Pedal Ground Tests Addendum.
[14] The control wheel moves from 78.5 degrees counter clockwise rotation to 78.5 degrees clockwise rotation.

"Control Column Position"

The "Control Column Position" EU conversion was established from the 23 separate pre-flight control column checks retained on the FDR recording. Since the control column sensor is the same type sensor as the rudder pedal sensor and had a similar installation as the rudder pedal sensor, it was assumed that the control column sensor behaved linearly. Therefore, the following look-up table, which used linearity between data points, was used to convert the raw recorded "Control Column Position" FDR values into EU:

	FDR "Control Column Position" (raw decimal counts)	Aircraft Control Column Position[15] (degrees)
Minimum	971	-11
Average-Neutral	2000	0
Maximum	3197	10

Filtered Flight Data Recorder Data

The analog signals from the following parameters were processed through the aircraft's System Data Analog Converter (SDAC) before being sent to the DFDAU as a digital signal.

- "Rudder Position"
- "Aileron Right Position"
- "Aileron Left Position"
- "Elevator Position"
- "Horizontal Stabilizer Position"

During the process of converting the analog signal into digital format, the SDAC applies a filter[16] to the data and the FDR records the filtered digital value. Therefore, these parameters are labeled as filtered in this report.

Final 2.5 Seconds of "Filtered Rudder Position" Data

The following "Filtered Rudder Position" values were recorded during the final seconds of the FDR recording:

[15] The control column moves 10 degrees aft position to -11 degrees forward position.
[16] The SDAC's filter was verified to be a first order lag filter with a 0.434 second time constant. Refer to the SDAC Bench Test Addendum.

"Filtered Rudder Position" (degrees)	Local Time (HH:MM:SS)	FDR SRN (elapsed seconds)
6.33	9:15:58.64	850.406
0.00	9:15:59.14	850.906
-123.43	9:15:59.64	851.406
0.00	9:16:00.14	851.906
0.00	9:16:00.64	852.406
0.00	9:16:01.14	852.906

Through testing[17], it was determined that if a non-computed data (NCD)[18] signal was sent to the DFDAU the FDR would record a value of 0.00. Since the maximum travel of the rudder surface is +/- 30 degrees, it can be assumed that the "Filtered Rudder Position" of –123.43 degrees recorded at 9:15:59.64 was an erroneous data point. The reason for this erroneous value is unknown.

"Radio Altitude"

During the initial takeoff rotation, the FDR parameter "Radio Altitude" recorded the following data:

"Radio Altitude" (raw decimal counts)	Converted "Radio Altitude" (feet)	Local Time (HH:MM:SS)	FDR SRN (elapsed seconds)
30	0	9:14:24.91	756.672
30	0	9:14:25.91	757.672
4095	4065	9:14:26.91	758.672
4095	4065	9:14:27.91	759.672
4095	4065	9:14:28.91	760.672
35	5	9:14:29.91	761.672
47	17	9:14:30.91	762.672

The radio altitude sensor is physically located aft of the main landing gear, therefore, during the initial takeoff rotation the "Radio Altitude" would record a negative value but instead the

[17] Refer to the SDAC Bench Test Addendum.
[18] The SDAC has the capability of marking the validity of data being sent to the DFDAU. This is accomplished by setting the bits in the Sign/Status Matrix (SSM) of the 429 data word. The DFDAU fitted to this aircraft is not capable of processing the SSM, therefore, would be unable to identify the validity of the data.

FDR data recorded a raw decimal value of 4095 which converts to 4065 feet. To determine if there was a problem with the DFDAU, American Airlines sent a similar make and model DFDAU to the DFDAU manufacturer, Teledyne Controls, for evaluation. Teledyne Controls determined that the DFDAU was not decoding the negative values of the "Radio Altitude" correctly. Therefore, during the takeoff rotation when the "Radio Altitude" would have been negative, the DFDAU outputted a maximum raw decimal value of 4095 instead. Therefore, the "Radio Altitude" FDR values recorded at 9:14:26.91, 9:14:27.91 and 9:14:28.91 are erroneous data points.

"Gross Weight" Data

The "Gross Weight" FDR parameter recorded the following data:

Recorded "Gross Weight" (metric tons)	"Gross Weight" Converted (pounds)	Local Time (HH:MM:SS)	FDR SRN (elapsed seconds)
158.3	348,991.8	9:13:46.58	718.344
158.0	348,330.4	9:14:50.58	782.344
157.8	347,889.4	9:15:54.58	846.344

Section IV – Time Correlation

The Aircraft Performance Group established the correlation between the FDR SRN to the Federal Aviation Administration (FAA) Air Traffic Control (ATC) time (also known as local time). Based on the information supplied by the Aircraft Performance Group Chairman, the time of each FDR SRN were adjusted to the ATC time by adding 32,508.234 seconds to each FDR SRN[19] as follows

ATC time (Local Time)= FDR SRN + 32,508.234 seconds.

Section V – Plots and Data in Electronic Format

Selected FDR parameters pertinent to the accident flight are presented in Attachment II in graphical format. There are a total of 8 plots. Attachments II-1 (selected general flight FDR parameters), II-3 (selected flight control FDR parameters), II-5 (selected spoiler FDR

[19] Refer to the Aircraft Performance Group Chairman's Aircraft Performance Study for more details.

parameters), II-7 (selected engine FDR parameters) and II-8 (selected discrete FDR parameters) have a time scale from 09:13:35 to the end of the FDR recording at 09:16:01.23.

Attachment II-2 has the same parameters as Attachment II-1 excluding the following parameters:

- "Flap Position"
- "Ground Speed"
- "Right Main Landing Gear Squat" discrete
- "Left Main Landing Gear Squat Switch" discrete
- "Nose Gear Squat Switch" discrete

Attachment II-4 has the same parameters as Attachment II-3. In addition, Attachment II-6 has the same parameters as Attachment II-5. Attachments II-2, II-4 and II-6 have an expanded time scale from 09:15:34 to the end of the FDR recording.

Attachment III contains all the data graphed in Attachment II in comma delimited (CSV) format files. Additionally, the FDR parameters "Greenwich Mean Time (GMT) hours", "GMT minutes" and "GMT seconds" data are also provided in Attachment III in comma delimited (CSV) format file. As noted previously, Attachment III only exists as electronic files in the docket.

Cassandra Johnson
Mechanical Engineer
FDR Specialist

Enclosures:

Attachment I: Flight Data Recorder Parameter Listing Sorted By Word Location

Attachment II: Selected Flight Data Recorder Data Plotted (8 Plots Total)

Attachment III: Flight Data Recorder Data in Comma Delimited (CSV) Format Files for the Following:

- FDR Data Plotted in Attachment II
- "GMT hours", "GMT minutes" and "GMT seconds"