NATIONAL TRANSPORTATION SAFETY BOARD

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

September 15, 2003

FDR Time Latency Addendum 4 to the 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 (FDR) 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)

C. ADDENDUM

The National Transportation Safety Board requested that Airbus quantify the FDR time latency associated with selected FDR recorded parameters. The attached document is Airbus's response to this request. Additionally, this document is referenced in the Aircraft Performance Group Chairman's Aircraft Performance Study Addendum 1.

Cassandra Johnson
FDR Specialist, Mechanical Engineer

Enclosure: Airbus Document Reference Number 506.0009/2001 Edition 04 (9 pages total)

AIRBUS

DEPARTEMENT :EID SECTION : 506 GO : PROGRAMME : A300-600 : DATE : Iss. 04 : 15/06/2003	REFERENCE :506.0009/2001 EDITION : 04 PROJET : REF PROJET : O.F. : ATA : CLIENT :	TOME : REV :

TITRE : AAL587 ACCIDENT (A300-600 MSN 420) AT NEW YORK ON 12 NOV. 2001 - TIME DELAYS FOR RECORDED PARAMETERS

AUTEURS : Andre MAUMUS

RESUME :

This technical note gives the ranges of time delays for a list of parameters, between the time of their theoretical instantaneous physical measurement and the time at which they are time-stamped for their recording by the Flight Data Recorder.

The given values have been established from the data supplied by the system design specialists in charge of the computers which acquire, process, transmit, concentrate, and record these parameters.

This study has been performed in the frame of the AAL587 (A300-600 MSN 420) accident in NEW YORK, on 12 November 2001.

IMPORTANT NOTE : The values of ranges of time delays given in this note must not be used in another application (i.e. in the frame of another event) without prior re-assessment.

Issue 4 : issue 4 supersedes and cancels the previous ones.
- it provides confirmation on assumptions made in previous issues on the Teledyne DFDAU and FDR equipment which has been installed by STC on AAL A/C.
- it introduces a slight correction on the AOA parameter time delay.

MOTS CLES : TIME DELAYS ; FDR ; RECORDED ; PARAMETERS
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LIENS :

NATURE : NT,	LANGUE : E	ANNULE REMPLACE : Y	PAGES A ARCHIVER : 10

DOCUMENT EXTERNE	SIGNATURES
EMETTEUR : EDITION : 04 REF : DATE:	A. MAUMUS Flight Safety Enhancement / EID

TIME DELAYS BETWEEN PARAMETER MEASUREMENTS AT THEIR SOURCE AND THEIR RECORDING ON FDR

The purpose of this technical note is to give the ranges of recording time delays for a given list of parameters, between the time of their theoretical instantaneous physical measurement and the time at which they are time-stamped for their recording on the FDR. This study has been made in the frame of the AAL 587 accident at NEW YORK, on 12 November 2001 (A300-600 MSN 420 A/C).

1. GENERAL -

1.1 - Chain of elements between a parameter sensor and the recording of the parameter values - Factors which intervene in the time delays of parameter recording

Typically, for a given parameter, the measurement/acquisition/treatment/emission/recording chain includes the following elements :

- Sensor

- "mother" computer, where the parameter goes through the following steps :
  · **Input (I/P)** :
  - sensor signal acquisition
  - conversion into digital form (or adaptation if the sensor already sends its signal under digital form), pre-conditioning, storage of the parameter value in RAM
  · **Computation** (computer functional application with particular treatments as required, like filtering)
  (but the parameter does not go necessarily through this treatment step, it may go directly from I/P to O/P)
  · **Output (O/P)**
  - preparation for emission (formatting, e.g. adding label/SSM for ARINC 429 parameter, buffer loading)
  - emission under serial digital form

- possibly, intermediate computer (s)
  The parameter data may not go directly from the "mother" computer to the DFDAU, but may go via one or two intermediate computers, for A/C system architecture reasons.

- DFDAU
  This computer acts as a data concentrator and interface between the A/C systems and the Flight Data Recorder.

- FDR or SSFDR
  This is the Flight Data Recorder.

The time delay between the moment when a parameter physically takes a given value and the moment when this value is recorded in the FDR within the specified tolerance may depend on :
- the processing time of the computers,
- the particular treatments such as filtering,
- the refresh rate.

1.2 - Processing

Each computing element (i) of the chain (including the sensor if it is a digital sensor transmitting data on a bus) has its own processing time relative to the acquisition, further treatment and emission of a given parameter (p), called Ppi.

When the parameter is transmitted after computer treatment for the basic computer functions, Ppi may vary from one computer cycle to several, depending on the computer real time architecture and the involved software tasks.

Ppi may be very short, when specialized I/O (Input / Output) processors or automata perform the parameter treatment for their direct re-transmission without waiting for further and longer internal treatments by the other operational processors dedicated to the basic computer functions.
Some intermediate computers only act as "mail-boxes" for their input / output parameters.

Ppi may be steady, driven by a regular software task sequencing, or vary from Ppi min to Ppi max depending on the computer real time architecture. For example, in case of a Task Scheduler, Ppi will change depending on the task priority and the load of the computer.

1.3 - Filtering

A given parameter may be filtered by the computers for several purposes (anti-aliasing O/P filter because of the limited acquisition performance of the users, O/P filter for parameter indicating, for display stability, etc.). And filters introduce time lags which depend on their nature (1st or 2nd order or else), their calculation algorithms, and the shape, amplitude and dynamics of the input signals.
For example, for a ramp signal input, a 1st order filter introduces a time lag which is equal to its time constant.

Let us call respectively fpi and Fpi the minimum and maximum time lags that the filter may introduce, affecting parameter p in computer i, given the possible variations (amplitude, dynamics) of parameter p.

With digital filters, the treatment is performed over several computer cycles.

Naturally, fpi and Fpi depend on the frequency spectrum of the I/P parameter signal.
For this reason, the tables in the next pages cannot provide time delay values associated with filters, they indicate when there is a filter, with its characteristics (nature, time constant, Laplace transforming equation).

1.4 - Parameter Refresh

Each computing element (i) transmits parameter p at defined refresh and transmit rates.
Most often, the refresh rate is equal to the transmit rate. Let's call RRpi the refresh rate of parameter p transmitted by computer i.

RRpi may be steady, thanks to the proper sequencing of transmissions by Real Time Clocks, or it may change from RRpi min to RRpi max according to the computer real time architecture.

A common error is to add Ppi and RRpi systematically. It may be appropriate in some cases, but not in all cases. Refer to section 1.6.

1.5 - Delays introduced by the DFDAU and FDR

On the AAL A/C, the DFDAU and FDR equipment (Teledyne, original development made by Hamilton Standard) has been installed by STC.

Their processing time and the resulting time delay that they induce on parameter recording is very short (< 20 msec.), as per Teledyne's reply :

Quote "

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ven. 07/03/2003 00:50
Andre:
Subject:  AA Flight 587 DFDAU data acquisition throughput delay
Reference: Your e-mail to Norm Smith of Teledyne Control on 21 January 03

Andre the DFDAU that was operational on AA flight 587 was original
manufactured by Hamilton Standard and its internal operation was not
designed by Teledyne, therefore it's internal operation is not common
knowledge.   We currently do product support on the units and support the
customer base using it.

To get the answer to you question of delays of acquisition and outputting
of data required to have the software (that is in machine language) reverse
engineered to determine the operation of the unit and therefore the delays.
This DFDAU acquires and outputs data at a rate of 64 twelve bit words per
second. That is one word every 15.625 ms.
The Dits data and Analog data (pot as an example) are acquired at word "N"
and outputed at word "N+1". That indicates that the acquisition is up to
15.625 ms prior to being outputed to the recorder. All parameters are
acquired at word "N" and outputed at word "N+1" example data "A" is
acquired during word 10 (15.625 ms ) and then sent to the recorder at
during word 11( 15.625 MS), Parameter "B" acquired at word 11 and sent to
the recorder at word 12 etc.

Note: The Dits parameter 429 bus update rate is also a factor in the total
delay thorough the system delay veritable.

Discrete data both Dits and Analog are done differently. Every 125 ms all
discrete inputs are acquired and stored in a buffer. The above definition
of acquisition cycle of acquire( word N) and output ( word N+1) is used but
the discrete data is fetched from the stored buffer. The data in the stored
buffer may be up to 125 ms old so the discrete data may be as old as 125 ms
plus the 15.625ms normal acquire and out put delay.

If you have any questions on this please feel free to contact me.

Sincerely

Larry Fox
Director of Aircraft Integration / Certification
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" Unquote

Notes :

- all signals under the scope of this study fall into the “Dits data and Analog data (pot as an example)” category,
- The Dits parameter 429 bus update rate has been taken into account in the results given in tables 1, 2, 3 given on pages 6, 7, 8, as explained in the next paragraph.

1.6 - Overall window (lower and upper limits) for time delays

So for a given parameter p, the time delay Tp between the measurement of the signal and the recording of the corresponding data on the FDR is as follows :

$$\sum Ppi\ min + \sum fpi \quad < \quad Tp \quad < \quad \sum Ppi\ max + \sum RRpi\ max + \sum Fpi \quad .$$

These are absolute minimum and maximum values. Several factors may "reduce the window" :

a) these computers often have an acquisition rate for their input signals which is higher than the transmit rate of the corresponding output parameters.

· the signal acquisition rate may be equal to the basic computer calculation cycle frequency, and the parameter delivered on the computer output bus at longer time intervals will reflect an input signal which was acquired in the latest computer cycle(s) before the parameter transmission

· or the acquisition may be performed by specialized and fast processor or automaton which acquire all incoming input signals at a high rate and immediately store them in a RAM.

If the parameter values are transmitted on the ARINC O/P bus at times n-1, n, n+1, the parameter value which will be transmitted at time n will not be an "old" value possibly stored just after the last parameter transmission at time n-1. It will be the last value acquired by the computer I/P part and immediately stored in the RAM.

In these cases, the time delay may be equal to 1 or 2 computer cycles only (and not to the time between 2 successive parameter transmissions), or be very short, driven by the rythm imposed by the I/P specialized processor or automaton. In these cases, Ppi will be underlined, RRpi does not intervene. **But the time delay due to the refresh rate of the upstream computer cannot be avoided, it has to be added.**

b) sometimes, the maximum parameter time delay may be equal to RRpi, which will be underlined in the tables, and Ppi does not intervene.

In certain cases, the computer supplier provides the calculation result for the "maximum transport delay" information (case of the IRU), which includes all (Ppi, RRpi, and Fpi for a typical defined I/P signal). In these cases, this value will be put in the Ppi column, and will be underlined in the tables.

2 <u>APPLICATION</u> -

2.1 - Pitch angle, Roll angle, Magnetic heading parameters (See table 1)
"mother" computer = IRU
"intermediate" computer = SGU-EFIS

2.2 - A/C acceleration parameters (nx, ny, nz) (See table 1)
Sensor = 3 - axis accelerometer installed at the A/C CG
"mother" computer = none
"intermediate" computer = none
(Direct accelerometer acquisition by the DFDAU)

2.3 - Pitch, Lateral, Yaw control surface positions (See table 2)
sensors = synchros
"mother" computer = SDAC
"intermediate" computer = none

2.4 - Pitch control position (pitch control column position) (See table 2)
(retrofitted control input parameter following FAR 121 requirements, sensor (potentiometer) directly acquired by the DFDAU
"mother" computer = none
"intermediate" computer = none

2.5 - Lateral control position (control wheel position) (See table 2)
(retrofitted control input parameter following FAR 121 requirements, sensor (potentiometer) directly acquired by the DFDAU
"mother" computer = none
"intermediate" computer = none

2.6 - Yaw control position (rudder pedal position) (See table 2)
(retrofitted control input parameter following FAR 121 requirements, sensor (potentiometer) directly acquired by the DFDAU
"mother" computer = none
"intermediate" computer = none

2.7 - Pitch Trim Surface position (See table 3)
sensor = synchro
"mother" computer = SDAC
"intermediate" computer = none

2.8 - Angle Of Attack (See table 3)
sensor = swept vane type with a synchro
"mother" computer = DADC
"intermediate" computer = SGU-EFIS

2.9 - Calibrated Airspeed (CAS) (See table 3)
sensor = pitot and static pressure probes
"mother" computer = DADC
"intermediate" computer = SGU-EFIS

TABLE 1

			IRU Honeywell 10 MCU		***SGU EFIS***		***DFDAU / FDR***		
Parameter/Label	***Variable***	***AAL Acronym***	***Pp min/Pp max***	***RRp***	***Pp min/Pp max***	***RRp***	***Pp***	***(Sampling Rate)***	***TOTAL Tp***
Pitch angle / 324	θ	PTCH	50 (F1)	20	11 / 60	47/67	20	(1000)	80 < Tp < 150
Roll angle / 325	φ	ROLL	50 (F2)	20	11 / 60	47/67	"	(1000)	80 < Tp < 150
Magnetic heading / 320	ψ	MHDG	110 (F3)	40	38 / 130 + F4	93/137	"	(1000)	170 < Tp < 320

(F1) and (F2) : includes 1^{st} order filters, fc = 8 Hz . (F3) : includes 1^{st} order filter, fc = 2 Hz . F4 = 1^{st} order filter, fc = 8 Hz

			SENSOR	***---***	***DFDAU / FDR***		
Parameter/Label	***Variable***	***AAL Acronym***			***Pp***	***(Sampling Rate)***	***TOTAL Tp***
Longitudinal acceleration	nx	LONG	3 axis accelerometer at frame 46/47		20	(250)	20
Lateral acceleration	ny	LATG	//		"	(250)	20
Vertical acceleration	nz	VRTG	//		"	(125)	20

All values expressed in ms (milliseconds)

TABLE 2

			SENSOR	SDAC		DFDAU / FDR		
Parameter/Label	**Variable**	**AAL Acronym**		**Pp min/Pp max**	**RRp**	**Pp**	**(Sampling Rate)**	**TOTAL Tp**
Pitch control surface position / 314	δq or dq	ELVA (or B)	1 synchro at the outer end of the RH elevator	20 + F1	125	20	(250)	Tp driven by Fp
Lateral control surface position (ASA) / 310	δp or dp	AILL (or R)	2 synchros (LH and RH side ASA control surfaces)	20 + F2	125	"	(1000) (with Teledyne eqpt)	"
Yaw control surface position / 312	δr or dr	RUDD	1 synchro at the bottom of the rudder	20 + F3	125	"	(500)	"

F1 = F2 = F3 = 1st order filter with time constant = 434 ms

All values expressed in ms

			SENSOR	---		DFDAU / FDR		
Parameter/Label	**Variable**	**AAL Acronym**				**Pp**	**(Sampling Rate)**	**TOTAL Tp**
Pitch control position / (CAPT & F/O)	δqm or dqm	CCLA (or B)	retroffited control input parameter with STC eqpt (potentiometer)			20	(500)	20
Lateral control position (CAPT & F/O)	δpm or dpm	CWHLA (or B)	retroffited control input parameter with STC eqpt (potentiometer)			"	(500)	"
Yaw control position / (CAPT & F/O)	δrpal or drpal	RUDPA (or B)	retroffited control input parameter with STC eqpt (potentiometer)			"	(500)	"

All values expressed in ms

TABLE 3

			SENSOR	SDAC		DFDAU / FDR		
Parameter/Label	**Variable**	**AAL Acronym**		**Pp min/Pp max**	**RRP**	**Pp**	**(Sampling Rate)**	**TOTAL Tp**
Pitch Trim surface position / 315	dqmt or rdmt or dqt	STAB	1 synchro	20 + F	125	20	(1000)	Tp driven by Fp

F = 1st order filter with time constant = 434 ms

			DADC HONEYWELL		SGU EFIS		DFDAU / FDR		
Parameter/Label	**Variable**	**AAL Acronym**	**Pp**	**RRp**	**Pp min/Pp max**	**RRp**	**Pp**	**(Sampling Rate)**	**TOTAL Tp**
Angle of Attack / 221	α	TADA 1 (or 2)	167 (F1) (for 1Hz I/P) + 50 (F'1)	62.5	35 / 250	203 / 240	20	(500)	270 < Tp < 550
Airspeed (CAS) / 206	Vc	CAS	100 (F2) (for 1Hz I/P)	125	35 / 250 + F3	203 / 240	20	(1000)	155 + F3 < Tp Tp < 495 + F3

(F1) and (F2) : includes *1st order filters*

F'1 : it represents the filter of the AOA sensor itself, this filter is equivalent to a 1st order filter with a 50 ms time constant

F3 = 2nd order filter. Its Laplace transformation function is : (1 / 1 + p) + (p / 1 + 10 p). For a ramp I/P signal of 3 kt/sec., it induces a time lag which reaches a max. of 700 ms after 2 sec., and slowly reduces to 0 in about 15 sec. .

All values expressed in ms