NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering

Washington, DC 20594

February 15, 2000

Flight Data Recorder - 10

Addendum 2 to Group Chairman's Factual Report

by Dennis R. Grossi

A. ACCIDENT

Location:	East Moriches, N.Y.
Date:	July 17, 1996
Time:	2031 local standard time
Aircraft:	Trans World Airlines (TWA) Flt. 800, B-747-131, N93119
NTSB Number:	DCA96MA070

B. PURPOSE

The Flight Data Recorder Group Chairman's Factual Report (FDRFR) dated February 28, 1997, contains graphs and tabular listings of the FDR data for Trans World Airlines Flight 800 (TWA800). In addition, the FDRFR contains a detailed description of how the FDR records data and how the playback system extracts and processes the recorded data. This Addendum was prepared to add to the description provided in the FDRFR and to clarify the source of some data that were presented.

C. SUMMARY

At the time of the accident, the FDR was recording data from TWA800 and was erasing data from TWA803 that had been recorded on July 16, 1996. Tabular files and graphs presented in the FDRFR show the end of TWA800 data and the transition to the older TWA803 data. The tabular data at time 20:31:12 that were lined through and labeled as "END of FLT 800 DATA have apparently been misunderstood by some reviewers of the data as having been recorded during TWA800[1]. In fact, the lined-through data are from TWA803 (as is demonstrated in the discussions below).

D. DETAILS OF INVESTIGATION

1. Physical relationship of UFDR and data on recording tape

The physical relationship between the UFDR tape transport erase and read/write heads and the recording tape is illustrated in the top portion of Figure 1. The reel-to-reel

[1] Two copies of page 42 from the FDRFR, February 28, 1997 are attached. The first copy shows the lined-through data from TWA803. The second copy is the updated version, from which TWA803 data have been deleted.

co-planar tape transport uses two sets of read/write and erase heads. When the tape is moving from the right reel to the left reel, as in the case of TWA800, erase and read/write heads 1357 are active. The heads operate on one of eight available data tracks at any given time. As the tape moves past the erase head, the data are erased on the active track. As the tape continues to move past the read/write head, data are written to the tape on the same track. As a result, an approximate 3-inch gap in the data appears between the newest and oldest data on the tape in which the old data has been erased'.

Figures 1, 2, and 3 contain composite photographs of the portion of the recording tape that was adjacent to the heads when the crash enclosure was opened following the accident. The photographs show the tracks of recorded data and the erase/write gap on track 2[3]. The oldest data from TWA803 is to the right of the gap on track 2 and the newest data from TWA800 is to the left. The inter-record gaps (IRG), which are produced when the tape is advanced during the Checkstroke™ process are also evident in the photographs as the evenly spaced gaps in the signal. The IRGs appear at 1- second intervals. The data blocks are between the IRGs and contain 64 12-bit words and an 8-bit preamble and 8-bit post amble (768 + 16 bits). Expanded images of the beginning and end of the erase-write gap, which identify the end of TWA800 data and the oldest data from TWA803, are also shown in figure 2.

The two sets of analog waveform graphics on figures 1 & 3 were generated by different systems. The waveform graphic in the middle of figures 1 and 3 was generated by "WAVES+"@, a software package developed by Enthropic Research Laboratories, Inc[4]. The wave form graphics at the bottom of figures 1 and 3 were generated by the FDR Recovery Analysis and Playback System (RAPS), the software used to process the FDR data. WAVES+ was used to produce a graphic of the signal generated during a playback of the FDR tape. The vertical axis indicates signal amplitude and the horizontal axis indicates tape distance. The erase-write-gap is evident by the absence of a signal as indicated by the area where the amplitude is approximately zero.

The amplitude of the signal decreases on either side of the erase-write-gap, a situation that does not normally occur. This decrease in amplitude was also present on the other 7 recording tracks at the same point on the tape. Similar signal degradation has been observed recently on a UFDR recovered from an extended water immersion. The decreased amplitude of the signal did not prevent the recovery of the affected data.

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[2] The read/write and erase heads are separated by approximately 2.8 inches. The Checkstroke™ process (described on page 3 of the FDRFR) results in a slightly larger erase/write gap.

[3] The recorded signal is normally not visible. The visualization of the magnetic signals on the tape was achieved through the application of "Magna-See"@. Magna-See is a commercially available product that contains a veryfine iron powder suspended in a fast-drying liquid. When applied to a magnetic recording medium, such as magnetic tape, the iron powder will align to the shape of the magnetic fields of the recorded data. The magnetized areas appear gray while the demagnetized areas retain their original dark color.

[4] WAVES+ uses a set of interactive signal process programs designed to provide direct support of analog I/O, signal filtering, spectrum analysis, quantization, signal editing, file editing, signal plotting etc.

2. Data recovery

The data are recorded in a recurring sequence of data frames. A complete data frame includes 43 12-bit binary words with a sync code as the first word[5]. RAPS was used to identify the analog waveform signal and to convert the analog waveform signal to binary coded decimal (BCD) values, which are further processed to produce the engineering unit values displayed in the data plots and tabular listings.

RAPS signal processing electronically displays the IRGs and the erase/write gap. However, when the conversion to BCD and engineering units takes place, the gaps are ignored. RAPS determines time by counting the number of data bits recovered, not by the length of tape processed. If data are not present, as in the gaps, time is not increased. Thus, the graphical and tabular data are presented as a continuous data set even though a 3-inch gap separates the data on the tape.

Further, RAPS will not properly process the binary data if the sync word cannot be identified. The sync word detection logic requires that the sync word is in a specific location in the binary data stream or sync will be lost. Typical causes for the loss of sync are noisy data signals from worn or damaged tapes, incomplete data frames due to electrical power interruption to the FDR, or the transition across the erase/write gap. Normal use of RAPS to decode data in which the sync word has not been identified results in anomalous or spurious engineering values. However, the binary data can often be manually decoded (using the data edit features of RAPS) to determine the engineering values.

The FDR recording for TWA800 ended when power to the recorder was lost. As with most accidents, the last data for TWA800 contained a partial data frame that necessitated manual decoding of the binary data. Therefore, the data edit feature of RAPS was used to identify and recover all of the data recorded during TWA800. This process identifies the last partial data frame recorded just prior to the erase-write-gap.

Graphics at the bottom of figures 1 and 3 show expanded versions of the analog waveform at the end of TWA800 data and the start of the oldest data recorded during TWA803. The bit detection capability of RAPS is also displayed with the bit cell boundaries and associated binary values (zero and one). The last data bits were associated with word 4 bits (1-9) of a data frame and the 8-bit postamble of the data block (figure 3). The month is recorded in word 4 bits (5-8) as a "7" or July. The postamble that defines the end of a data block process starts in bit 10 as a "1" followed by 7 "0", and is aligned with prior preambles/postambles (i.e., IRGs).

The continuation of the data frame (word 4 bits (10-12) and words 5 through 43) would have appeared in the next data block after a preamble and would also have been associated with the time 20:31:12. However, there were no subsequent data for TWA800 that were recorded. Power to the recorder was lost in the middle of a data frame and at a point just after the postamble was written, but before the next preamble

[5] **A** data block (768 data bits) may contain one complete data frame and portions of one or two data frames; or portions of two data frames.

could be written. This is consistent with the analog waveform in figures 1 and 3, which shows a full size data block just prior to the erase-write gap.

The data for TWA803, which appears just after the erase-write-gap, starts with a partial data block, which is also evident in the analog waveform and in the photographs in figures 1-3. In addition, the data starts with a partial data frame, one that is out of sync with the previous partial data frame from TWA800. TWA803 data (after the erase-write-gap) were processed by RAPS as though there were no gap on the tape. The data that are lined through in the tabular listing at time 20:31:12 are the out-of-sync remnants of a partially erased data frame recorded during TWA803, the previous day.

The playback software must identify at least two successive sync words located at the proper interval before sync can be reestablished and the data correctly decoded. Therefore, the binary data just after the erase/write gap had to be manually decoded. On the erase side of the erase-write-gap, the first data are bits (10-12) of word 6 from TWA803, which are unassigned and contained no information. Those bits would have been the next to be erased. Words 7 and 8 contained GMT minutes and seconds, respectively. Bits (1-4) of word 7 contain the unit value of minutes (3) and bits (5-8) contain the tens value of minutes (2), which decoded as 23 minutes. Similarly, bits (1-4) of word 8 contain the unit value of seconds (1) and bits (5-8) contain the tens value of seconds (1), which decoded as 11 seconds.

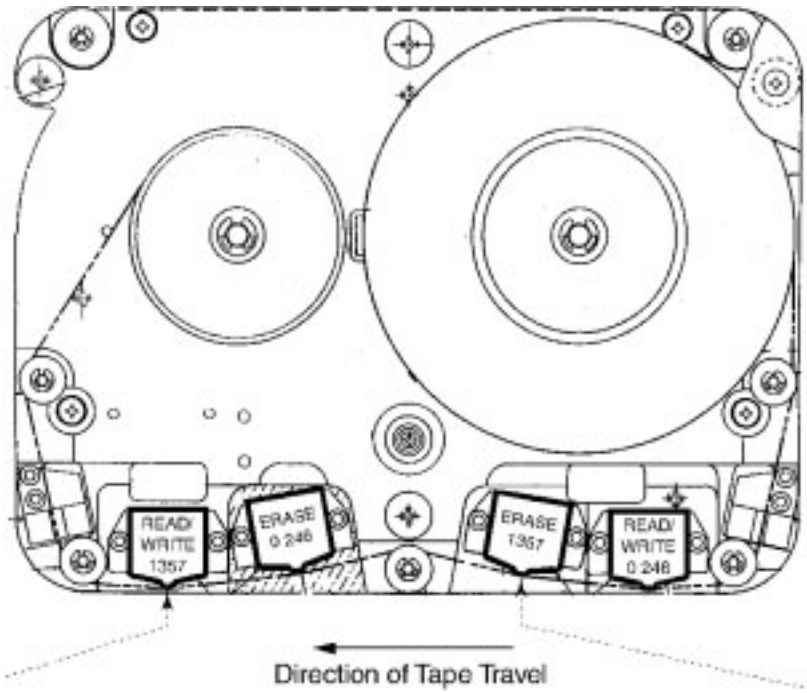
3. Timing of data

Timing recovered from the FDR is elapsed time; the zero time reference is assigned at the beginning of the transcribed data. As stated previously, RAPS does not recognize the transition from TWA800 data to TWA803 data. Therefore, elapsed time is stored as a continuous time reference that bridges the transition from TWA800 to TWA803 data. The local time presented in the tabular listing is determined by correlating the elapsed time of the FDR data to the local time presented with Boston Air Route Traffic Control Center audio recording.[6] Once the correlation is defined, the local time also appears to be continuous through the transition from TWA800 to 803 data.

Dennis R. Grossi
National Resource Specialist Flight Data Recorders

[6] The time correlation process is described on pages 5 and 6 of the FDRFR.

UFDR TAPE TRANSPORT and RECORDING



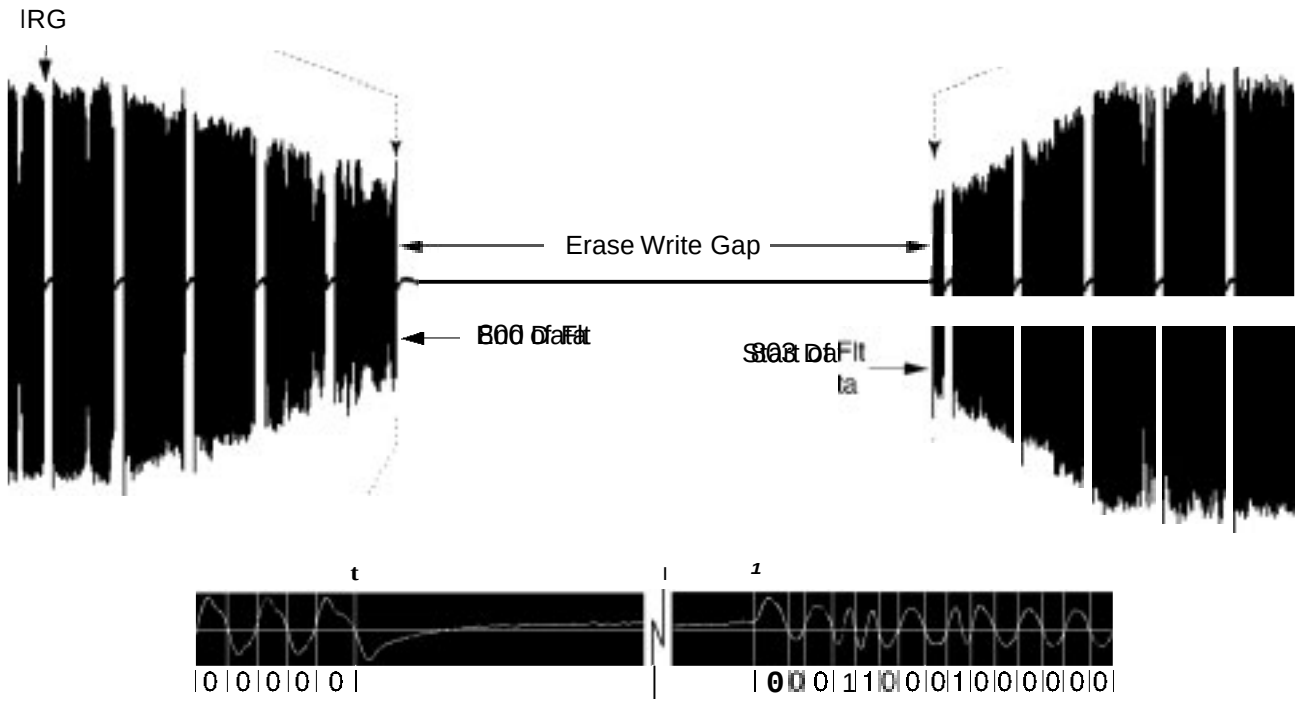
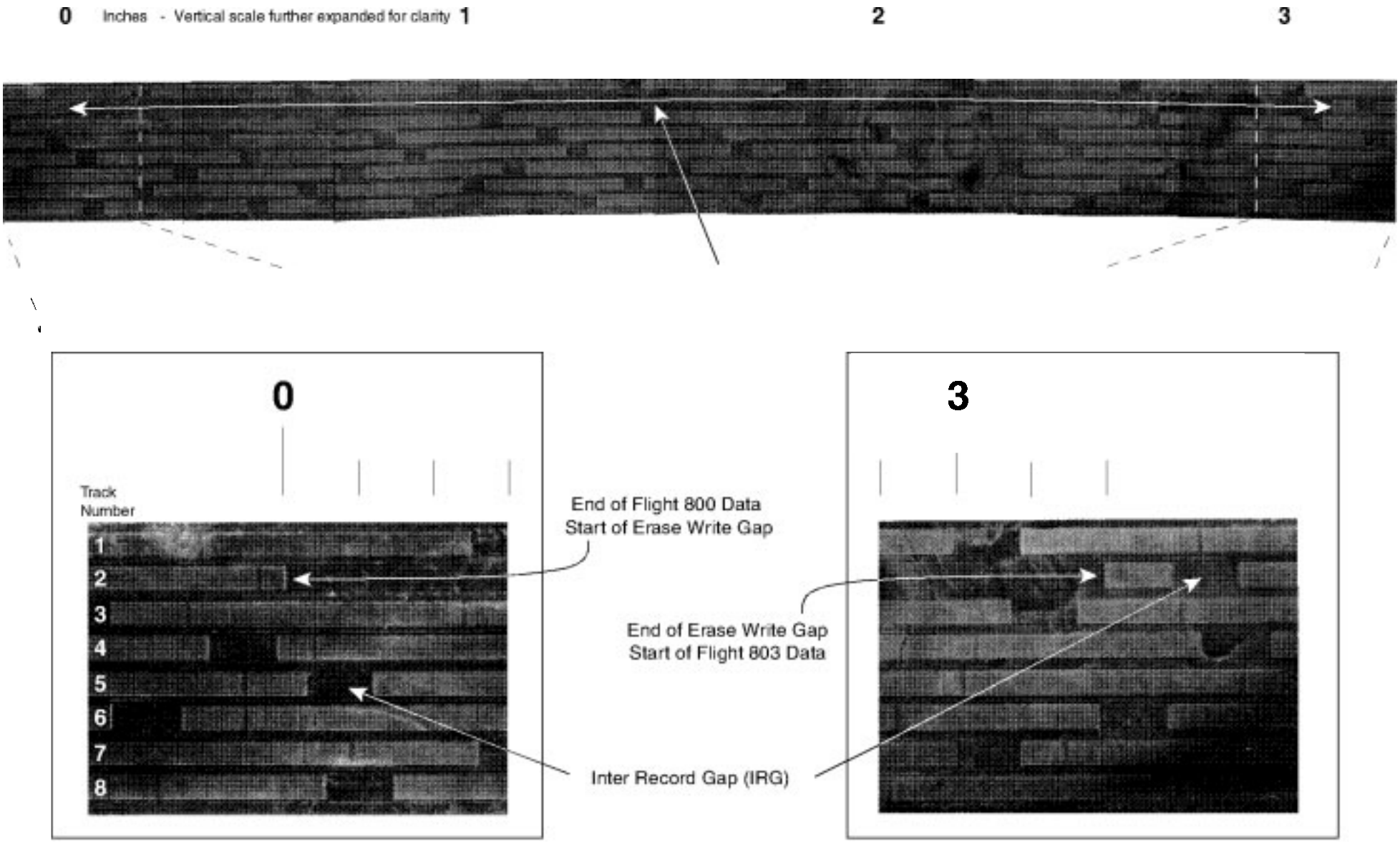


Figure 1

COMPOSITE PHOTOGRAPH of DFDR RECORDING TAPE



Portion *medium with Magna-See applied to show the magnetic fields of the recorded data. Dark areas indicate absence of recorded data.*

R&PS EXP&ND&D WAV&F@RM

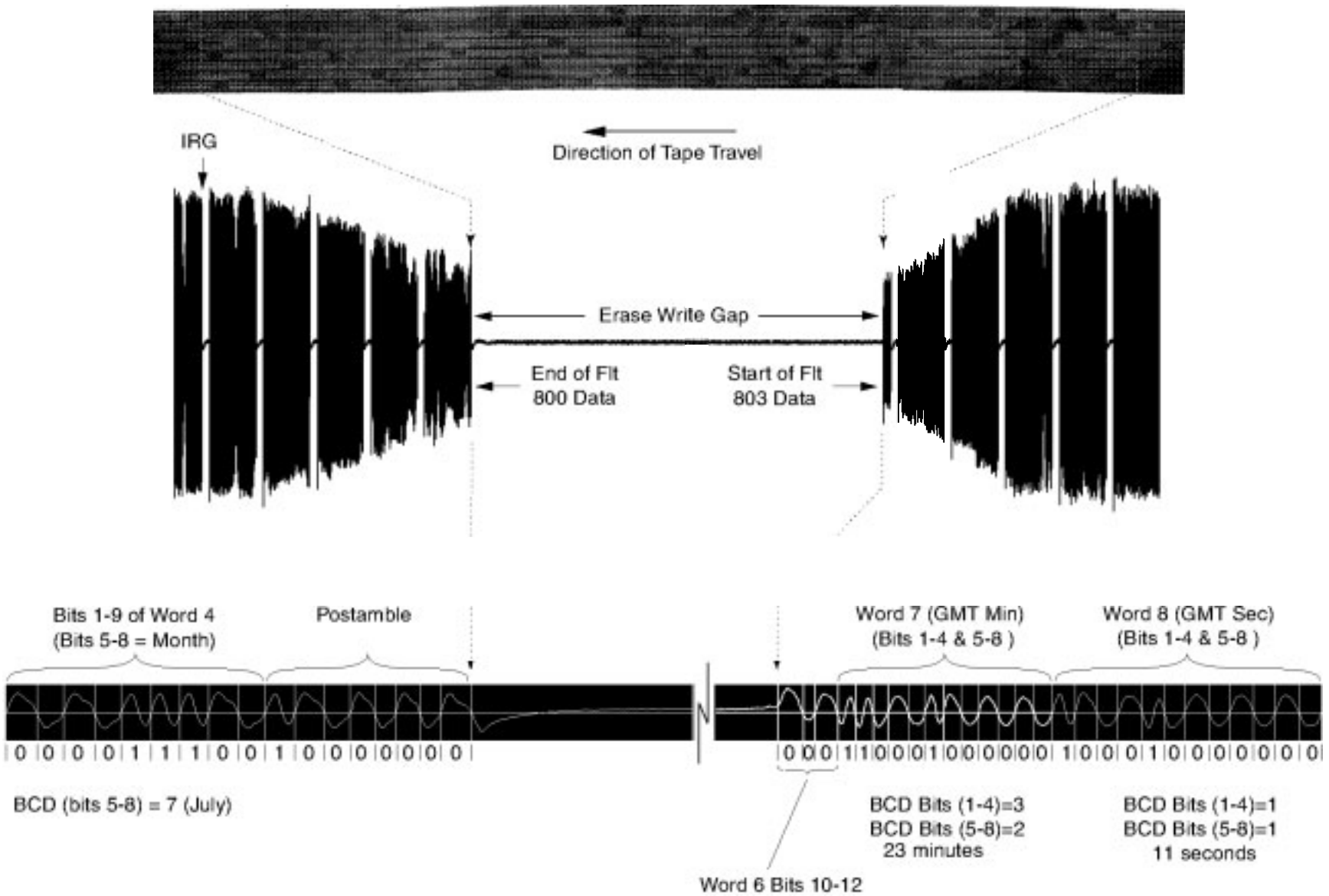


Figure 3

10/15/99

LOCAL TIME (hr:min:sec)	INS Alt. (FEET)	IAS (KNOTS)	Pitch Angle (degrees)	Elevator Position Right (degrees)	Mag. Heading (degrees)	Roll Angle (degrees)	Rudder Position (upper) (degrees)	Angle of Attack (degrees)	EPR Engine 1 (ratio)	EPR Engine 2 (ratio)	EPR Engine 3 (ratio)	EPR Engine 4 (ratio)	Long. Accel (g)	Vert. Accel. (g)	WOW	Pitch Trim Stab Pos (degrees)	
20:31:05	13637.	287	4.3	0.2	82	1	0.72	3	1.31	1.25	1.25	1.29	0.08	0.89	Off	3	
		289					0.63	3	1.31	1.29	1.29	1.30	0.08	0.91	Off		
								3					0.08	0.89			
													0.08	0.90			
20:31:06	13652.	290	4.3	0.0	82	1	0.63	3	1.31	1.30	1.30	1.29	0.08	0.90	Off	3	
	13667.		4.3	0.4	82	1	0.63	3					0.08	0.92		3	
							0.63	3					0.08	0.92			
													0.08	0.92			
													0.08	0.92			
20:31:07	13682.	256	4.0	0.4	82	1	0.63	3	1.31	1.30	1.30	1.29	0.08	0.92			
		257					0.63	4	1.31	1.30	1.29	1.29	0.08	0.92	Off	3	
							0.63	3					0.08	0.92	Off		
													0.08	0.92			
20:31:08	13702.	280	4.0	0.4	82	1	0.63	3	1.31	1.29	1.29	1.29	0.10	0.92			
	13717.		4.0	0.4	82	1	0.72	3					0.10	0.92	Off	3	
							0.63	3					0.10	0.92		3	
													0.10	0.92			
													0.10	0.91			
20:31:09	13730.	280	4.0	0.3	82	0	0.63	3	1.31	1.29	1.29	1.29	0.10	0.90			
		280					0.72	3	1.31	1.29	1.29	1.29	0.10	0.90	Off	3	
							0.72	3					0.10	0.90	Off		
													0.10	0.90			
													0.10	0.90			
20:31:10	13747.	290	3.8	0.1	82	0	0.63	3	1.31	1.29	1.29	1.30	0.10	0.90	Off	3	
	13757.		3.8	0.4	82	0	0.72	3					0.10	0.90		3	
							0.72	3					0.10	0.90			
													0.10	0.90			
20:31:11	13772.	288	3.6	0.1	82	0	0.72	3	1.30	1.29	1.30	1.30	0.10	0.90	Off	3	
		286					0.72	3	1.30	1.29	1.29	1.29	0.10	0.89	Off		
							0.72	3					0.10	0.89			
													0.10	0.89			
													0.10	0.89			
20:31:12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	→ END of FLT. 800 DATA
			0.2	-0.2	276	0	-36.54	10					0.10	-1.02			
20:31:13							0.72	3					0.09	1.02			

Local Time (ref. CVR)	MSL Alt. (FEET)	IAS (KNOTS)	Pitch Angle (degrees)	Elevator Position Right (degrees)	Mag. Heading (degrees)	Roll Angle (degrees)	Rudder Position (upper) (degrees)	Angle of Attack (degrees)	EPR Engine 1 (ratio)	EPR Engine 2 (ratio)	EPR Engine 3 (ratio)	EPR Engine 4 (ratio)	Long. Accel (g)	Vert. Accel. (g)	WAF	Pitch Trim Stab Pos (degrees)
20:31:01	13512.00	288 288	4.7	0.2	92	-1	0.62 0.83	3 3	1.31	1.28	1.31	1.30	0.11 0.10 0.10 0.10 0.10	0.90 0.90 0.90 0.90 0.90 0.90	Off	4
20:31:02	13537.00 13667.00	296	4.3 4.2	0.2 0.0	82 82	0 0	0.72 0.70 0.72	3 3 3	1.31	1.28	1.30	1.29	0.10 0.10 0.10 0.10	0.90 0.93 0.93 0.93	Off	4 3
20:31:03	13637.00	289 290	4.7	0.1	78	0	0.72 0.72 0.72	3 3 3	1.31 1.31	1.28 1.28	1.30 1.30	1.29 1.29	0.10 0.10 0.10 0.10 0.10 0.10	0.94 0.90 0.91 0.90 0.90 0.90	Off Off	3
20:31:04	13697.00 13617.00	296	4.3 4.7	0.3 0.2	82 87	0 1	0.72 0.72 0.72	3 3 3	1.31	1.28	1.30	1.30	0.10 0.10 0.10	0.90 0.89 0.89	Off	3 3
20:31:06	13637.00	287 285	4.2	0.3	80	1	0.70 0.63 0.72 0.62 0.62	3 3 3 3 3	1.30 1.31	1.29 1.29	1.30 1.29	1.28 1.30	0.10 0.10 0.10 0.10 0.10 0.10 0.10	0.88 0.88 0.88 0.85 0.85 0.89 0.90 0.92	Off Off Off	3 3 3
20:31:07	13887.00 13882.00	291 287	4.3 4.0	0.4 0.4	80 80	1 1	0.62 0.63 0.62 0.63 0.63 0.63	3 3 4 3 3 3	1.31 1.31	1.30 1.30	1.30 1.29	1.28 1.29	0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10	0.91 0.91 0.92 0.92 0.91 0.91 0.90 0.92	Off Off	3 3
20:31:08	13702.00 13717.00	288	4.0 4.0	0.4 0.4	80 80	1 1	0.62 0.70 0.63 0.72 0.72 0.72	3 3 3 3 3 3	1.28 1.31 1.31	1.29 1.29 1.29	1.28 1.29 1.29	1.28 1.29 1.29	0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10	0.91 0.91 0.92 0.92 0.91 0.90 0.90 0.90 0.88 0.88 0.88 0.88	Off Off Off Off	3 3 3 3
20:31:10	13747.00 13757.00	290	3.6 3.6	0.1 0.4	92 82	0 0	0.63 0.72 0.70 0.72 0.72 0.72	3 3 3 3 3 3	1.31 1.30	1.29 1.29	1.29 1.30	1.30 1.30	0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10	0.90 0.90 0.90 0.90 0.90 0.90 0.90 0.90 0.90 0.90 0.90 0.90	Off Off	3 3 3 3
20:31:12	End of Flight 800 Data															