Addendum 2

to FDR Group Chairman Factual Report - 10

DCA96MA070

submitted
September 9, 1998

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering

Washington, D.C. 20594

July 12, 1998

Flight Data Recorder - 10

Addendum 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

This Addendum was prepared to provide a more detailed description of the methods used to obtain the data contained in the Flight Data Recorder Group Chairman's Factual Report for Trans World Airlines Flight 800 (TWA800) dated January 9, 1997 (FDRFR). This report contains additional information for TWA Flight 803 (TWA803) on July 16, 1996, but no new data for TWA800.

C. SUMMARY

On July 17, 1996, about 2031 eastern daylight time, a Boeing 747-131, N93119, operated as TWA800, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK), Jamaica, New York. All 230 people aboard the airplane were killed. The airplane, which was operated under Title 14 Code of Federal Regulations (CFR) Part 121, was bound for Charles De Gaulle International Airport (CDG), Paris France. The flight data recorder (FDR) and cockpit voice recorder (CVR) ended simultaneously, about 13 minutes after takeoff.

The FDR, a Sundstrand Model UFDR (s/n 6707), was recovered from the Atlantic Ocean on July 24, 1996, and transported to the Safety Board's FDR Laboratory in the custody of the Federal Bureau of Investigation (FBI). The FDR arrived at the Safety Board's Laboratory at approximately 3:00 AM, on July 25, 1996. The damaged recorder was disassembled and the magnetic tape recording medium removed for playback. The initial readout of the recorded data was performed on July 25, 1996.

At the time of the accident, the data recorded for TWA803, on July 16, 1996, was being overwritten by the data fromTWA800. Approximately 6 hours of data recorded during TWA803 remained on the FDR.

The oldest data retained by the FDR was recorded while TWA803 was cruising at 33,000 feet on a heading of 272° in a wings level attitude, and at an airspeed of approximately 300 knots. TWA803 was a regularly scheduled international passengers flight from Charles De Gaulle Airport (CDG), France to John F. Kennedy (JFK), New York. Plots of selected parameters recorded during the last 7 minutes of TWA800 and the remaining portion of TWA803 are attached.

C. DETAILS OF INVESTIGATION

1. Transition of data From Flight 800 to Flight 803

This report describes the methods use to determine the end of the data recorded during TWA800, and the transition to the data recorded for TWA803 on July 16, 1996. Although the FDRFR clearly identifies the end of TWA800 data, a portion of the data recorded during TWA803 has mistakenly been analyzed as if it were recorded during TWA800. The data in question are the values written during TWA803, that are listed at time 20:31:12, in Attachment II, of the FDRFR. These values were transcribed as unsynchronized data and were labeled as "END of FLT 800 DATA", and a line was drawn through them.

It has been the Safety Board's practice to include the unsynchronized transition data in FDR Factual Report to show the point at which the transition from the newest to the oldest data occurs. This unsynchronized data typically appear as aberrant values, and can be used to identify the transition from the newest to oldest data. In the event of an accident, great care must be taken to insure that valid values that may appear as aberrant as a result of the circumstances of the accident are properly identified and included in the accident report. The methods used by the Safety Board to verify that all of the data recorded during TWA800 were recovered and properly processed are described in the following discussion.

As with most accidents, the last data for TWA800 contained a partial data frame (a complete data frame includes 43, 12-bit words with the sync code as the first word). The FDR recording for TWA800 ended when power to the recorder was lost. This occurred as word 4, which records the month, was being written. As noted in the FDRFR, the first aircraft performance related parameter, vertical acceleration, was recorded in word 11. Therefore, the partial data frame being written at the time the recorder stopped would have contained no aircraft performance data. The tabular data contained in the FDRFR only listed airplane performance parameters. The data that appeared in the tabular listing at time 20:31:12, were out-of-sync remnants of a UFDR postamble and a partially over written data frame recorded during TWA803, the previous day. The time reference presented in the tabular listing was derived from FDR elapsed time and therefore, would not have been affected by the loss of sync as the data transitions from TWA800 to TWA803.

2. Methods Used to Identify End Of TWA800 Data

The process of identifying the end of TWA800 data began by noting the position of the recording tape relative to the FDR erase and read/write heads. The initial search of the 8 tracks of recorded data was conducted relative to this area of the tape. Figure 1, contains a photograph of the portion of the recording tape that was adjacent to the

heads when the crash enclosure was opened following the accident. The photograph shows the magnetic signals of the recorded digital data, and identifies the end of the recording for TWA800 and the beginning of the earliest data recorded for TWA803.

The recorded signal is normally not visible. The visualization of the magnetic signals was achieved through the application of "Magna-See"®. Magna-See is a commercially available product that contains a very fine iron power 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 area appear dark gray while the demagnetized areas retain their original color.

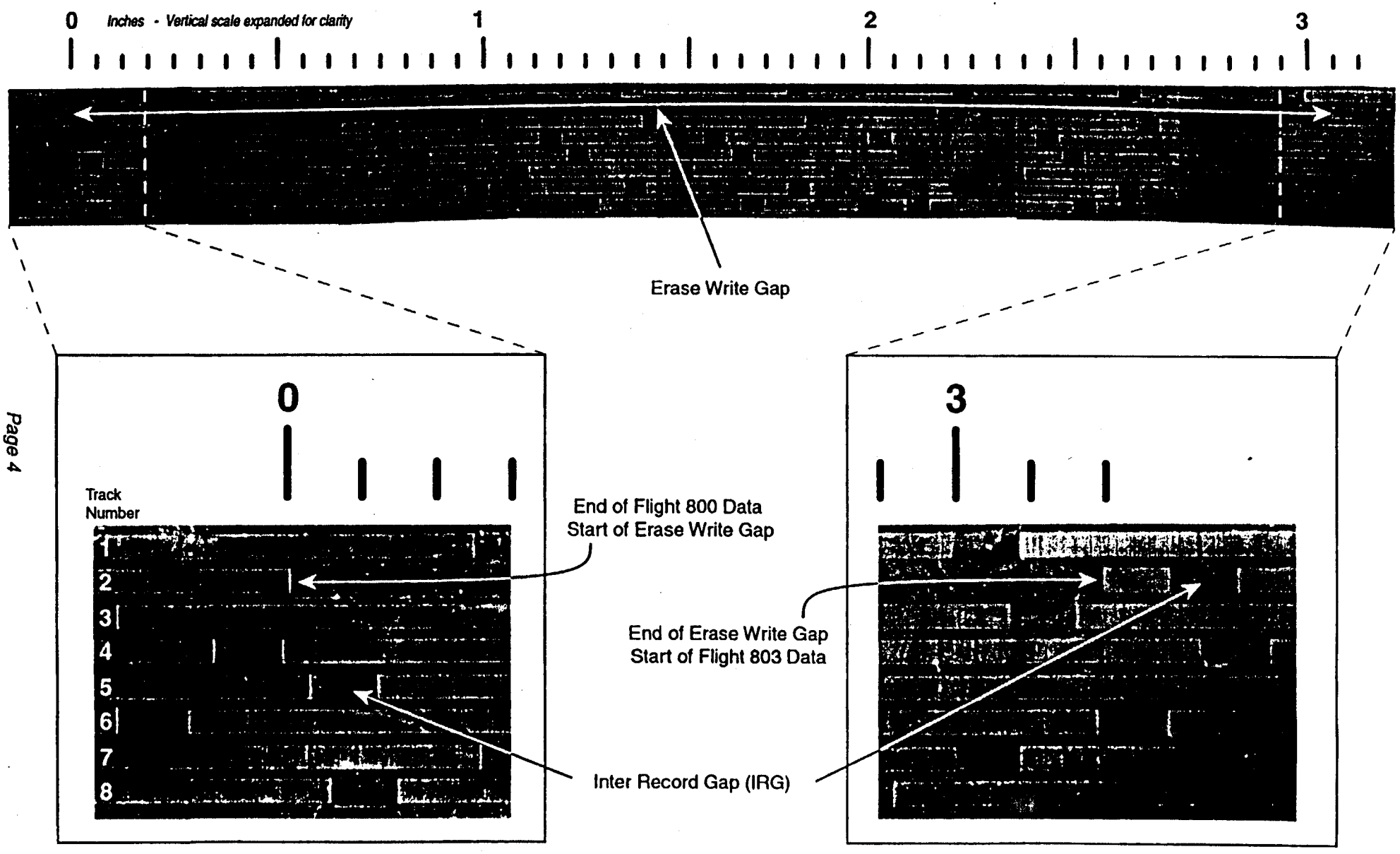
Magna-See was used to provide a optical depiction of the UFDR's unique digital recording characteristic for this report, but was not used to recover any data. The primary characteristics is the erase-write-gap, which appears on track 2 as labeled in figure 1. The erase write gap is a little over 3 inches long, the approximate length of tape path between the erase and write heads (see figure 2). The inter record gaps (IRG), which are produced when the tape is advanced during the Checkstroke™ process described on page 3 of the FDRFR, are also evident as the evenly spaced gaps in the signal. The IRGs appear at one second intervals. Expanded images of the beginning and end of the erase-write-gap, which identify the end of TWA800 data and the earliest data from TWA803, are also shown in figure 1.

The physical relationship between the UFDR tape transport erase and read/write heads and the recording tape, along with the associated electronic signals and digital data are illustrated in Figure 2. The reel to reel co-planar tape transport uses two sets of read/write and erase heads. When the tape is moving from right to left, erase and read/write heads 1357 are active, and when the tape is moving from the left spool to the right spool heads 0246 are active. The tape transport is bi-directional, switching tracks and direction when the end of tape is sensed. As a result the serial data stream, which is recorded on one track at a time, will have a gap between the newest and oldest data that approximates the distance between the erase and write heads.

Therefore, the location of the erase-write-gap on the recording tape is one of the best methods of identifying the transition from the newest to the oldest data. Prior to writing to the tape, the oldest data are erased by an erase head located approximately 3 inches ahead of the write head (see Figure 2). As a result, a gap or approximately 3 inches, where no data are recorded, will exist between the oldest and the newest data. This is commonly referred to as the erase-write-gap, and only appears between the last recorded data and oldest recorded data. The erase write gap will not be apparent in the transcribed data that appears in the tabular listing or data plots, but is clearly identified in the electronic signal generated during playback and visible when Magna-See is applied, as shown in figure 2.

The electronic signals displayed in figure 2 were generated by the two different systems used to examine the analog wave form generated by the digitally written signal on the FDR tape. The plot in the middle of figure 2, was generated by a software

PHOTOGRAPH of DFDR RECORDING TAPE



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

Figure 1

UFDR TAPE TRANSPORT and RECORDING

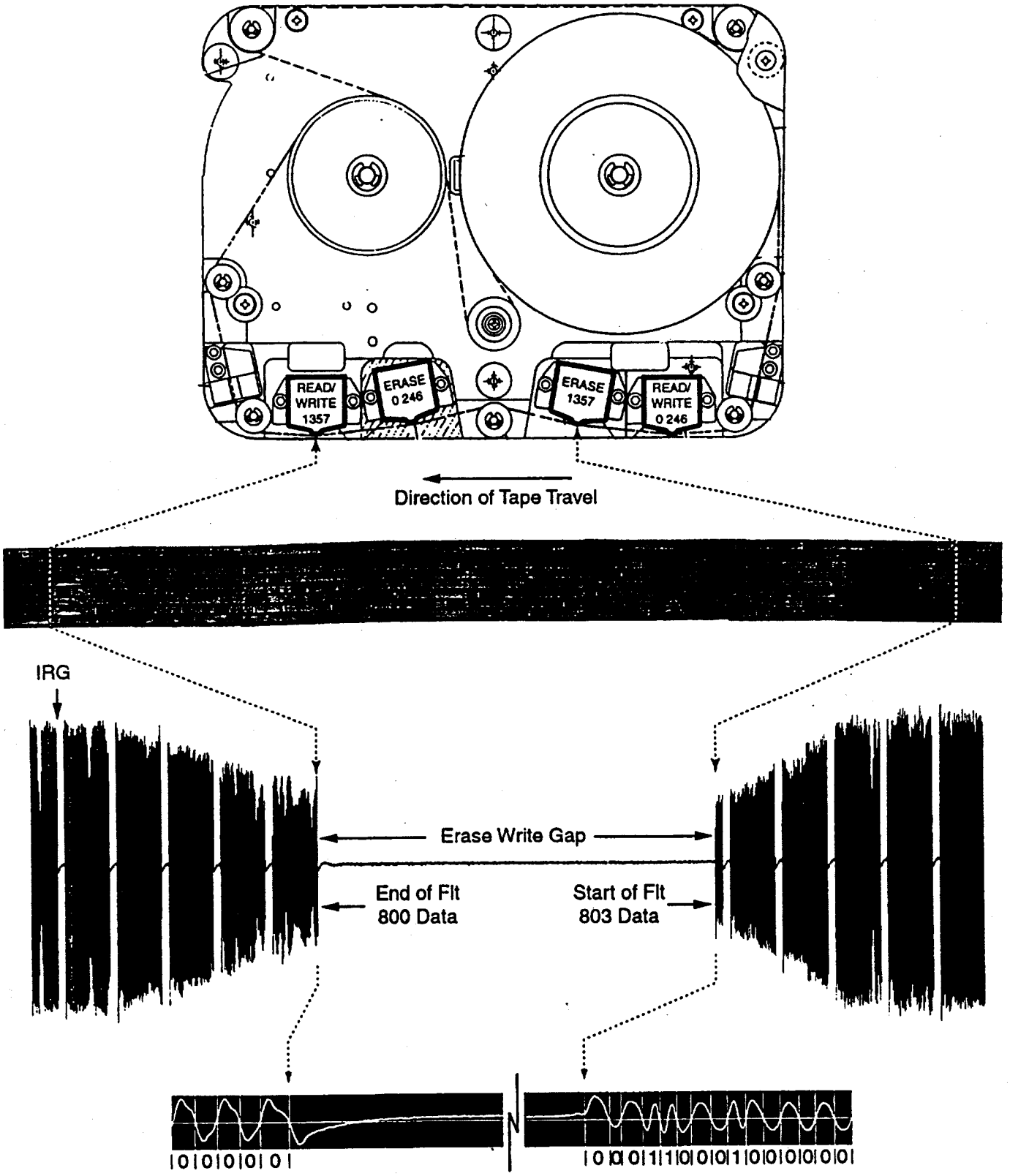


Figure 2

9/4/98

RAPS EXPANDED WAVEFORM

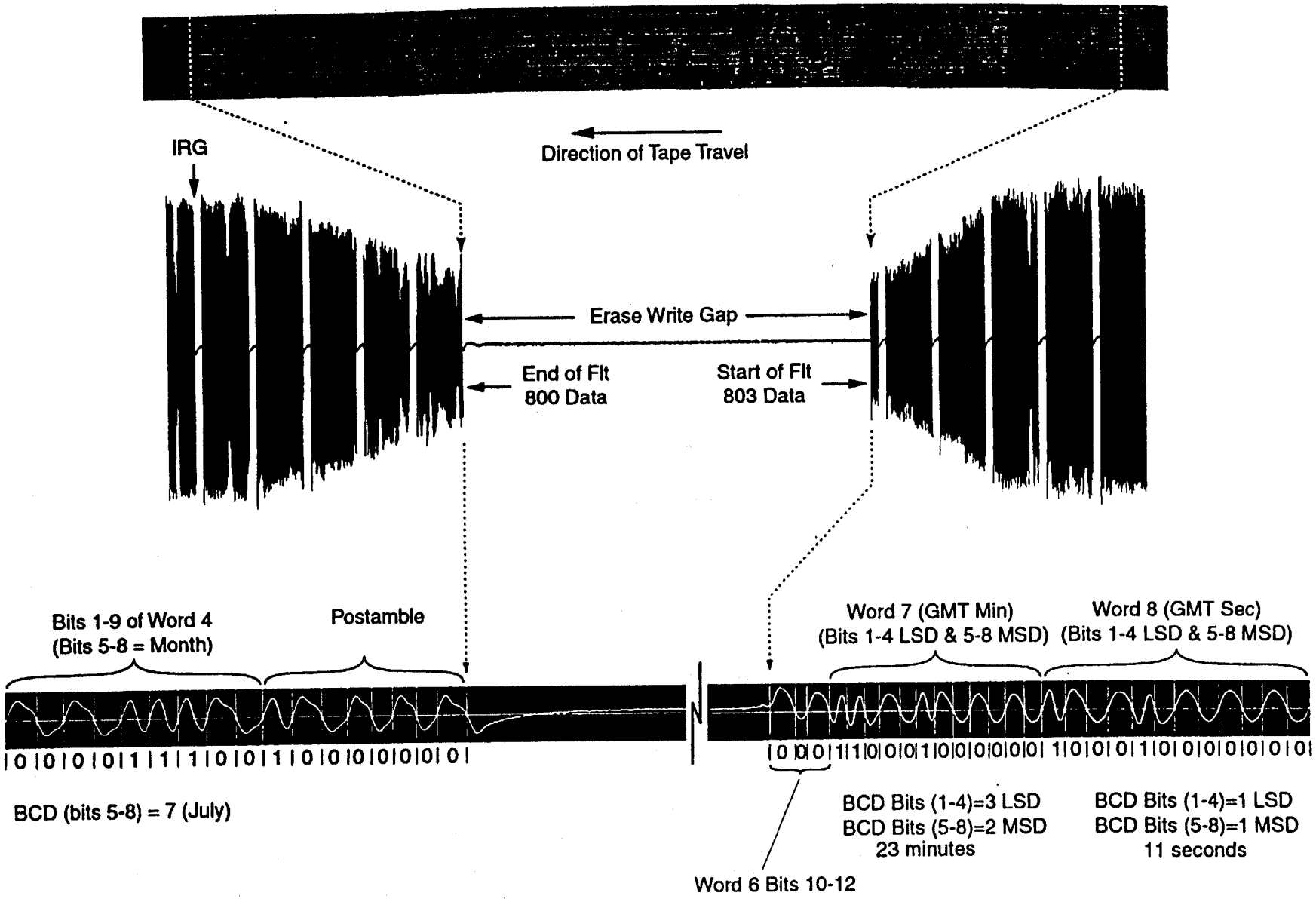


Figure 3

package titled "WAVES+" developed by Enthropic Research Laborites, Inc©. 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. WAVES+ was used primarily to produce a plot of the analog signal generated by the digitally recorded FDR data. The other method used FDR Recovery Analysis and Playback System (RAPS) software package to display an expanded version of the analog wave form along with the associated binary and engineering unit values.

The plot of the analog wave form produced by the WAVES+ software, shown in figure 2, indicates the transition from the data written during TWA800 and the data previously written during TWA803. 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.

As noted in the FDRFR the last data recorded for TWA800 occurred as a Checkstroke™ postamble was being written, indicating that 784 bit (768 data bits + 16 postamble/preamble bits) of buffed data had just been written. This is consistent with the plotted signal in Figure 2, which shows a full size data block just prior to the erase write gap. It should also be noted that the data for TWA803, which appears just after the erase write gap, starts with a partial data block, which is also evident in the visualized digital signal.

The amplitude of the signal also decreases on either side of the erase write gap. This decrease in amplitude was also present on the other 7 recording tracks at the same point on the tape. The length of tape containing the degraded signal approximates the amount of unreeled tape (see Figure 2). A similar signal degradation has been observed recently on a UFDR recovered from an extended water immersion. Further investigation of this phenomena is underway. The degradation of the signal did not prevent RAPS from recovering the affected data.

The wave form plot at the bottom of figure 2, was generated by RAPS. It shows a expanded version of the analog wave form generated by the digital data recorded at the end of TWA800 data and the start of the earliest data recorded during TWA803. The bit detection capabilities of RAPS is also displayed with the bit cell boundaries and associated binary values.

Figure 3, displays additional RAPS wave form plots and the associated binary and engineering unit values, and identifies word 4 as the word being recorded at the time power to the UFDR stopped and bits 10-12 of word 6 for TWA803 as the next bit to be erased. This FDR systems records data as binary coded decimal (BCD) values, which are further processed to produce the engineering unit values displayed in the data plots and tabular listings.

On the write side of the erase-write-gap, Word 4, recorded the month in bits(5-8) as a 7 or July. The postamble associated with the UFDR Checkstroke process starts in bit 10 as a "one" followed by 7 "zeroes", and is aligned with prior preambles/postambles (i.e., IRGs). A preamble starts with 7 zeroes followed by a one. Therefore, power to the recorder was lost at a point during the Checkstoke process just after the postamble was written, but before the preamble could be written.

On the erase side of the erase-write-gap, Bits (10-12) of word 6, which are unassigned and contained no information, are the first TWA803 data. Words 7 and 8 contained GMT minutes and seconds, respectively. The least significant digit (LSD) for minutes was recorded in bits (1-4), and the most significant digit (MSD) in bits (5-8), which decoded as 23 minutes. The similarly coded values for GMT seconds in word 8, decoded as 11 seconds.

The DOC data recorded in the adjacent complete subframes identified the data recorded on the write side of the erase write gap as TWA800, and the data on the erase side of the gap as TWA803.

3. Recovery of Documentary Data Written During Flights 800, and 803

In addition to the airplane performance parameters listed in the Flight Data Recorder Factual Report (FDRFR), the following non-mandatory documentary data (DOC) were recorded: Flight Number, Flight Leg, Date, and GMT. As non-mandatory parameters, DOC data have traditionally been unreliable, and therefore normally not referenced in FDR factual reports. However, in the case of TWA803 and TWA800 on July 17, 1996, the DOC data were correctly entered and recorded by the FDR.

Because DOC data are not required, it can not be assumed that it will be entered correctly. Therefore, the identification of the data recorded during an accident flight must rely on a more positive means. This normally involves correlating the physical location of the data to the FDR read/write heads and to know factual information such as; heading of runway in use, runway altitude, altitude of occurrence, heading at time of accident, etc. In the case of TWA800, the data were located by examining the recorded values for conditions consistent with the landing at JFK and the subsequent takeoff and climb of TWA800 and the termination of data at the erase-write-gap.

As described in the FDRFR, the local time reference was derived from the correlation the FDR elapsed time and the Boston Air Route Traffic Control Center audio recording. FDR GMT values are not used when more verifiable time references are available.

4. Discussion

It is important to recognized the difference between the data written to the tape and the data transcribed from the tape. For instance, the data from TWA803 recovered at the transition point or immediately after the erase-write-gap, in all probability, were written in-sync, but transcribed after the accident, as out-of-sync. This is a normal occurrence, as the sync reference (word 1) for a small portion of the oldest data *(less than a second)*, was erased as the data for TWA800 were written to the tape. In addition, the sync word for the partial data frame being written at the time of the accident would be transcribed in the proper sequence with prior data frames.

The RAPS software package used by the Safety Board to recover and process FDR data originally identified the data at time 20:31:12 as out-of-sync. This occurred because subsequent sync words recorded during TWA803, did not appear at the proper 43 12-bit word interval. In an effort to present all of the data recorded during

TWA800, the data edit feature of RAPS was used to declare the partial data frame recorded just prior to the erase-write-gap as a valid or complete data frame. This allowed the data after the erase-write-gap, or the data from TWA803, to be processed as thought it were recorded during TWA800, and is why it was lined-out in the tabular listing.

The Safety Board uses several methods to ensure that all data pertaining to TWA800 were recovered. The first method involved the correlation of the end of the Cockpit Voice Recorder (CVR) recording with the end of the FDR recording, and the previously discussed electronic and optical examinations of the recorded signal.

The correlation of the CVR and FDR from TWA800, as described on pages 5 and 6 of the FDRFR, indicated that both recordings ended simultaneously. The FDR recording ended at 20:31:12.27, and the end of the CVR recording occurred at 20:31:12.5. A correlation to within a 1/4 of a second, given the differences between the buffered digital signal written by the UFDR, and the analog signal recorded by the CVR, was considered to be consistent with the simultaneous loss of electrical power to the FDR and CVR.

The optical examination provided a means of correlating the physical dimensions of the erase and read/write heads with the location of the recorded digital data. This method was not used during the initial readout or the preparation of the FDRFR

The WAVES+ software provided a macro evaluation of the recording and corroboration of the RAPS wave form examination. The use of Flight Data Edit feature of RAPS, provided a continuous examination of the wave form at the bit level through the loss of signal at the write side of the erase-write-gap to the resumption of the wave form at the erase side of the erase-write-gap.

Examining the FDR recording at its rawest form, the analog wave form generated by the digitally recorded signal during playback, provides a complete and accurate record of all recorded values. The capability to examine the digital data at the bit level and simultaneously display the corresponding engineering unit value is extremely important to the data recovery process. The FDR group employed these method during the initial readout in July 1996, and is confident that all FDR data recorded during TWA800 have been recovered and properly decoded and presented.

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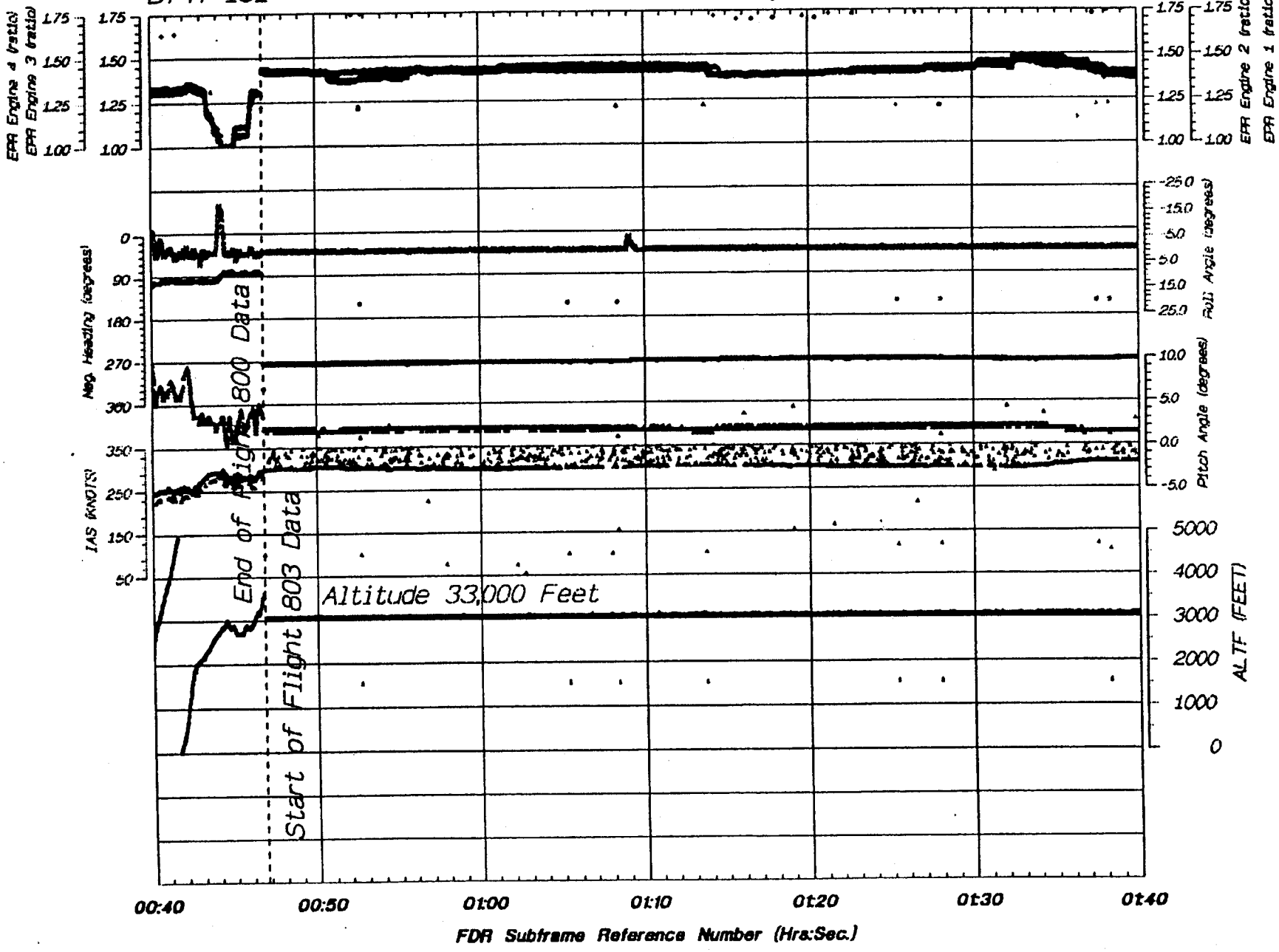
ATTACHMENT

Data Plots

TWA 800 / TWA 803

B747-131

July 17, 1996 / July 16, 1996



PLOT No.2

Revised: July 14, 1998

National Transportation Safety Board

TWA 800 / 803

B747-131

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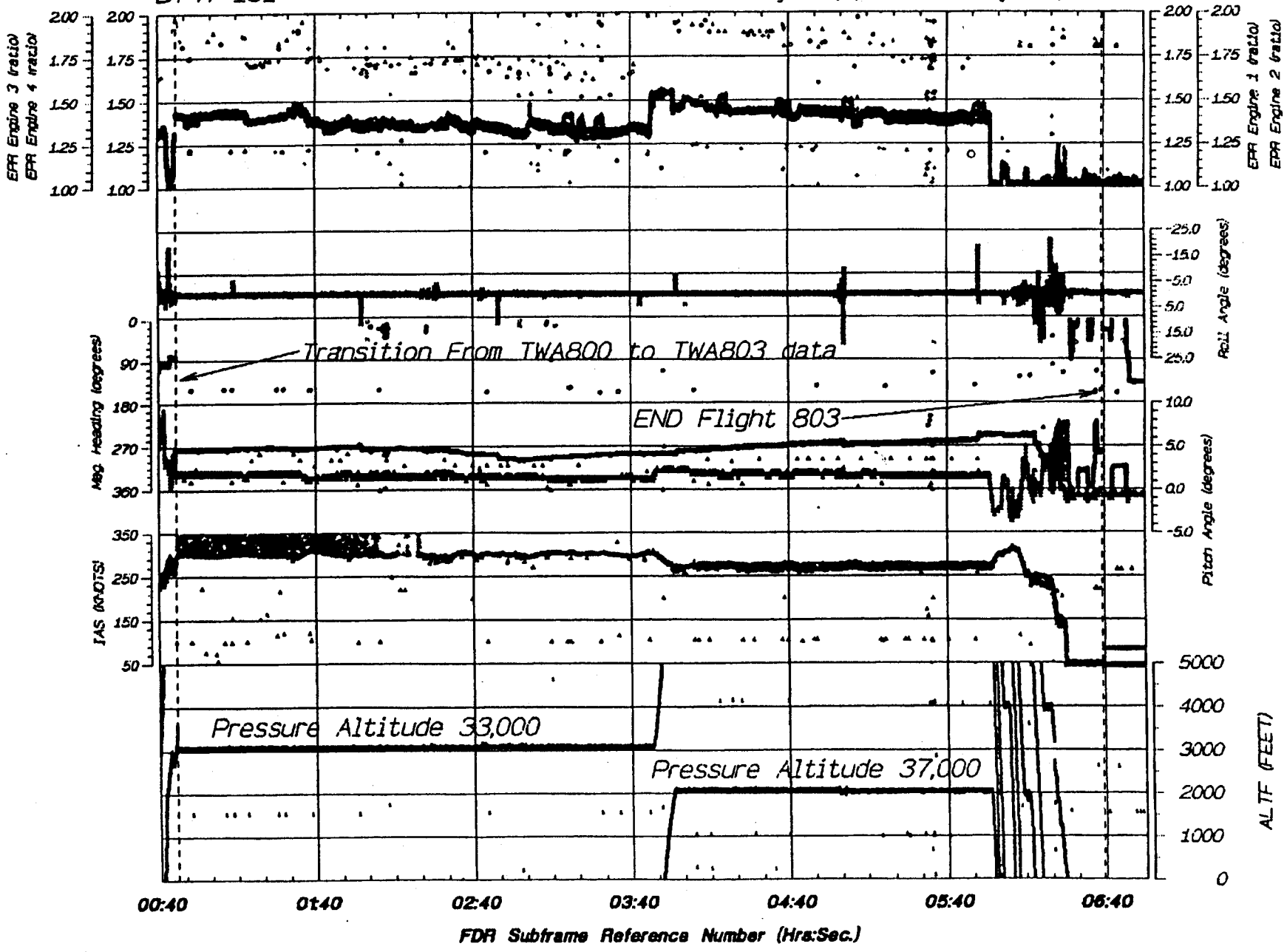

Plot No.1

Revised: July 14, 1998

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