Docket No. **SA-517**

Exhibit No. **13A**

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

Airplane Performance Study
Korean Air Flight 801
DCA97MA058

Guam
August 6, 1997

National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

February 24, 1998

Airplane Performance Study

I. Accident

NTSB #: DCA97MA058
Location: Nimitz Hill, Guam
Date: August 6, 1997
Time: Approximately 1542 GMT, 0142 Guam Local Time
Aircraft Type: Boeing 747-300, HL-7468, s/n 22487
Operator: Korean Air (FAR Part 129)

II. Group

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III. Summary

On August 6, 1997, approximately 0142 local time, Korean Air flight 801 (KA801), tail number HL-7468, crashed at Nimitz Hill, Guam while conducting an Instrument Landing System (ILS) approach to runway 06 left (06L) at Guam International Airport. This study develops a timehistory of the accident airplane's motion, pilot actions, and air traffic control actions during the accident approach. This study also reviews Federal Aviation Administration (FAA) Minimum Safe Altitude Warning (MSAW) program simulations and Allied Signal Ground Proximity Warning System (GPWS) simulations in order to estimate what altitude/terrain warnings should have been provided to the crew of the accident airplane with

their existing equipment. Lastly, this study reviews Allied Signal Enhanced Ground Proximity Warning System (EGPWS) simulations in order to estimate what additional altitude/terrain warnings would have been provided had the accident airplane been equipped with EGPWS.

Data used for this study include ground scar and wreckage location data (see Attachment I), Boeing 747 dimensions and system data, FAA radar data (see Attachment II), Jeppesen approach plate data (see Attachment III), flight data recorder (FDR) data and cockpit voice recorder (CVR) information (see Attachment IV), and terrain elevation data (see Attachment V). Plan and profile views of the radar data, approach plate data, terrain elevation data, and CVR information are presented in Attachment VI. Simulation results from the MSAW and GPWS/EGPWS simulations are presented Attachments VII and VIII, respectively.

The data indicate that at 15:11:51 GMT[1], while in cruise at 41,000 feet mean sea level (msl) altitude[2], a landing briefing was performed for the ILS runway 06 Left approach. During the briefing, there were comments about the glideslope [3], an MDA (minimum descent altitude) of 560 feet, and a HAT (height above terrain) of 304 feet. KA801 started its descent from 41,000 feet at approximately 15:14:05.

At 15:38:51, Guam CERAP[4] ATC provided KA801 with vectors to join the Guam runway 06L localizer from the west. At that time, KA801 was descending through 2,800 feet with the flaps extended 10 degrees and the landing gear up. KA801 turned left to 90 degrees magnetic heading to join the localizer and leveled off at approximately 2,600 feet. KA801 passed FLAKE intersection approximately 0.7 nautical miles (nm) north of FLAKE and was then cleared by CERAP for the ILS 06L approach. CERAP's clearance for KA801 included a statement that the glideslope was "unusable". At 15:39:48, KA801 read back the approach clearance for ILS 06L but did not acknowledge the glideslope notification. CERAP did not subsequently request read back of the glideslope notification.

At 15:39:50, KA801 turned left consistent with lining up with the localizer centerline. At 15:39:55, comments were made about the glideslope. Discussion about the glideslope continued until 15:40:00. A landing gear call was made and KA801 rolled back to wings level on a ground track consistent with that of the runway 06L localizer centerline.

KA801 started to descend out of 2,640 feet msl at approximately 15:40:13 at a point approximately 9 nm from the runway 06L threshold (approximately 5.7 nm from the Nimitz VOR/DME ~ thus 5.7 DME). The runway 06 Left ILS approach procedures for the glideslope out condition show that altitude should remain above 2,600 feet msl until inside 7.0 DME.

At 15:40:22, a comment was made about the glideslope. At 15:40:33, as the airplane was descending through 2,400 feet msl, a comment was made regarding 1,400 feet. At

[1] All times will be specified in GMT unless otherwise noted.
[2] The ATC automation altimeter setting at the time of the accident approach was 29.85 inches of Mercury.
[3] Glideslope data were not available for the runway 06 Left ILS approach because the glideslope equipment had been removed for maintenance in July. A Notice To Airmen (NOTAM) had been issued by the Federal Aviation Administration (FAA) indicating that the glideslope was not available. A copy of the glideslope NOTAM was found in the cockpit of the accident airplane with yellow highlighting on the text.
[4] Combined Center and Radar Approach Control.

15:40:37, a comment was made about the glideslope and 1,440 feet. At 15:40:42, CERAP advised KA801 to contact the Agana tower. KA801 subsequently advised Agana tower that they were intercepting the localizer 06 Left and the sounds of the configuration warning horn and altitude alert were heard. At 15:41:01, Agana tower cleared KA801 to land on runway 06 Left and advised that winds were 090 degrees at 7 knots. At about the same time, KA801 descended below 2,000 feet msl at a point approximately 6.8 nm from the runway 06 Left threshold (approximately 3.5 DME). The runway 06 Left ILS approach procedures for the glideslope out condition show that descent below 2,000 feet msl is not permitted until inside 1.6 DME.

The flaps began extending to 20 degrees at 15:41:13 as the airplane was descending through 1,800 feet msl, and KA801 advised Agana tower that they were cleared to land on runway 06 Left. Flaps began extending to 30 degrees at 15:41:23 and the configuration warning horn sounded. At 15:41:33, a comment was made about 560 feet followed by a call for a landing check. At 15:41:39, KA801 descended through 1,440 feet msl at a point approximately 5.3 nm from the runway 06 Left threshold (approximately 2.0 DME). The runway 06 Left ILS approach procedures for the glideslope out condition show that altitude should remain above 2,000 feet until inside 1.6 DME and should remain above 1,440 feet msl from 1.6 DME until inside 0.0 DME (inside the Nimitz VOR/DME).

At 15:41:42, as KA801 was descending through 1,400 feet msl, KA801's ground proximity warning system (GPWS) made a "one thousand" foot radio altitude callout. There was a comment about flags, gear and flaps and the sound of the altitude alert was heard at 15:41:45. At 15:41:48, there was a wiper call followed by a landing checklist call. At 15:41:59, as the airplane was descending through 1,100 feet msl, there was a not-in-sight call and the GPWS made a "five hundred" foot radio altitude callout.

At 15:42:14, as the airplane was descending through 840 feet msl, the GPWS made a "minimums minimums" callout. Checklist calls continued until 15:42:17 when the GPWS made a "sink rate" callout, then there was a comment about sink rate (FDR data indicate sink rate was approximately 1400 feet per minute at that time). At 15:42:19, as the airplane was descending through 730 feet msl, a 200 foot call was made followed by a missed approach call. KA801 was last recorded on radar at approximately 15:42:20.5 descending through 700 feet msl at a point approximately 3.8 nm from the runway 06L threshold (0.5 DME).

At 15:42:21, there was a not-in-sight call and a missed approach call. At 15:42:22, there was a go-around call and control column position began increasing about 1 degree per second. At 15:42:23, as the airplane was descending through approximately 680 feet msl, there was a go-around call, engine EPRs began increasing through 1.15, and airspeed began increasing through 135 KIAS.

At 15:42:24, as the airplane was descending through approximately 670 feet msl, the sound of the autopilot disconnect was heard, there was a comment about flaps, the flaps began retracting, pitch attitude and vertical acceleration began increasing, and the GPWS made a "one hundred" foot radio altitude callout. At 15:42:25, the GPWS began a rapid succession of radio altitude callouts "fifty" ... "forty" ... "thirty" ... "twenty". The first sounds of impact were recorded at approximately 15:42:26 as the "twenty" callout was made and as pitch attitude

increased through 3 degrees. Portions of the FDR data then began to fluctuate consistent with impact. Valid FDR data end at approximately 15:42:29 with increased nose up control column position and pitch attitude increasing through 8 degrees.

Ground scar measurements and survey data indicate KA801's first significant impact with terrain occurred when the #1 engine, main landing gear, and right wing hit a rising hill and trees at a surveyed elevation of approximately 660 feet msl. The aircraft subsequently impacted larger trees and rising terrain before coming to rest on descending terrain just below the Nimitz VOR/DME. The ground scars show aircraft attitude and flight path consistent with the radar and FDR data.

Post-accident FAA and NTSB research found that the Guam ARTS-IIA MSAW system was intentionally inhibited by the FAA inside a 54 nm ring around the Guam ASR radar. The MSAW inhibition was established as a means of eliminating what local air traffic controllers perceived as nuisance warnings. Post-accident MSAW simulation at the FAA's technical center in New Jersey showed that without the 54 nm MSAW inhibit ring, a visual and aural "LA" Low Altitude MSAW alert would have been generated for KA801 in the CERAP ATC building at approximately 15:41:22 as the airplane was descending through 1,700 feet msl (64 seconds prior to KA801's initial impact with terrain). The MSAW warning mode that was activated during the simulations was the "Current Approach Path Monitor".

Post-accident Allied Signal and NTSB research found that KA801's Allied Signal Mark VII GPWS functioned as it was designed to. Pull-up and terrain warnings were not issued because KA801 was in a landing gear/flap configuration where warnings are significantly diminished to allow for landings in mountainous terrain. Post-accident EGPWS simulation showed that had KA801 been equipped with EGPWS, an aural "caution" warning and a yellow visual terrain depiction on the weather radar scope would have been issued approximately 60 seconds prior to initial impact. An aural "pull up" warning and a red visual terrain depiction on the weather radar scope would have been issued approximately 45 seconds prior to initial impact.

IV. Details Of Investigation

A. Ground Scar and Wreckage Location Data

The United States Air Force conducted a survey of the accident site using a transit survey system. Their data were overlaid onto a 1:24,000 scale topographic map of the accident area for horizontal reference, and a vertical cross section of the terrain and accident site data was generated using the approximate center of the wreckage path as the cross section line (see Attachment I). The survey data indicate that KA801 first struck a small tree limb at a surveyed elevation of 673 feet msl. The #1 engine struck the ground hard approximately 415 feet later at a surveyed elevation of 662 feet msl. The landing gear tires struck the fuel pipeline approximately 440 feet after the first tree strike at a surveyed elevation of 650 feet msl. Subsequent deep landing gear ground scars were located approximately 485 feet after the pipeline contact at a surveyed elevation of 653 feet msl. The #1 engine resting place was approximately 965 feet beyond the initial tree strike and a surveyed elevation of 654 feet msl. tailcone in the main wreckage area

was located approximately 1870 feet beyond the initial tree strike at a surveyed elevation of 582 feet msl.

B. FAA Radar Data

Air Route Surveillance Radar (ARSR) data for the accident airplane were obtained from the FAA upon arrival Guam (see Attachment II). These data provide position and altitude for the accident airplane at approximately 12 second intervals. Airport Surveillance Radar (ASR) data for the accident airplane are not available according to the FAA because the Guam ASR is an older ARTS-II system and is not configured to record data. ASR data could have provided airplane position and altitude for the accident airplane at approximately 4.7 second intervals.

C. Jeppesen Approach Plate Data

The Jeppesen runway 06L ILS approach procedure plate was obtained from Korean Air (see Attachment III). The 2 Aug 96 version was determined to be the one in use based on the CVR conversation.

D. FDR and CVR Data

The FDR and CVR data are presented in the FDR and CVR group factual reports. FDR and CVR microphone keying data were aligned in order to establish a time correlation between the FDR and CVR (see Attachment IV). The alignment established that 10 hours 53 minutes and 28 seconds must be added to the FDR readout elapsed times in order to correlate with the CVR transcript time (CVR time is CERAP voice recording GMT). For example, FDR elapsed time 04:47:19 correlates to the CVR transcript time of 15:40:47 GMT. Overlays of CVR transcript excerpts onto graphs of the FDR data are shown in Attachment IV. The overlays show good correlation of key FDR and CVR events.

FDR altitude data and FAA radar altitude data were then aligned in order to establish a time correlation between the FDR/CVR times and the radar data times (see Attachment IV). The alignment established that 5.4 seconds must be subtracted from the FAA ARSR radar data times in order to correlate with the FDR/CVR times (CERAP voice recording GMT).

E. Terrain Elevation Data

Terrain elevation data were tabulated along the extended centerline of Guam's runway 06 Left using a USGS 1:24000 scale topographical map. The data are presented in Attachment V.

F. Plan and Profile View Plots of Radar Data, Approach Plate Data, Terrain Elevation Data, and CVR Information

The radar data, approach plate procedure data, terrain elevation data, and CVR

transcript were used to make annotated plots of the horizontal and vertical flight path of KA801 (see Attachment VI).

G. MSAW Simulation

NTSB staff worked with FAA staff from the FAA Technical Center to perform a simulation of how the Guam ARTS-IIA MSAW system would have performed had it not had the 54 nm ring inhibit area. Tech Center staff input a flight path consistent with that of KA801's radar data and watched a radar scope play back of the aircraft position and screen symbology. Repeated simulations showed an "LA" low altitude alert on the radar scope as the airplane was descending through 1,700 feet msl, about 64 seconds prior to KA801's initial impact with terrain. The ARTS-IIA automation output from the simulation is provided in Attachment VII.

H. GPWS and EGPWS Simulation

NTSB staff worked with Allied Signal staff to perform a GPWS simulation in order to estimate what altitude/terrain warnings should have been provided to the crew of the accident airplane with their existing equipment. EGPWS simulation was also performed in order to estimate what additional altitude/terrain warnings would have been provided had the accident airplane been equipped with EGPWS. Radio altitude was not recorded on KA801's FDR, so it was estimated for the simulations using radar position data and terrain elevation data. FDR configuration data were also used as inputs for the simulations.

The simulation results (see Attachment VIII) indicate that KA801's GPWS functioned as designed and did not provide terrain or pull-up warnings due to the landing configuration. Radio altitude callouts, "minimums" callouts, and a sink rate callout were appropriate for the flight path. The EGPWS simulation showed that EGPWS would have provided aural and visual terrain warnings to KA801 as much as 60 seconds prior to initial impact.

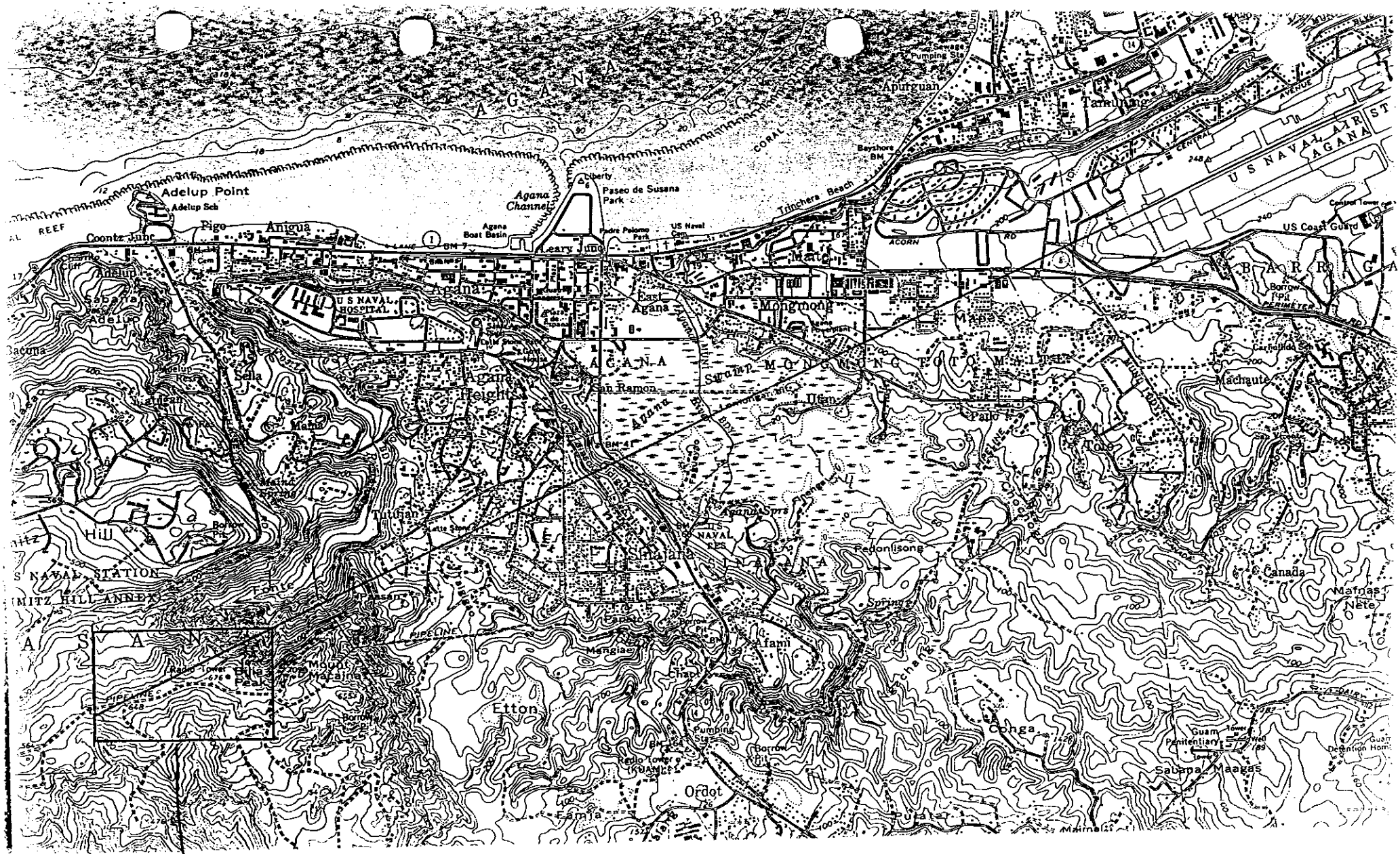
Charles Pereira
Aerospace Engineer

Attachments

Attachment I

Ground Scar and Wreckage Location Data

The complete US Air Force site survey data set that what used to create the plots on the following pages is contained in the Structures Group Factual Report.



ACCIDENT AREA
SEE BLOW-UP
PLOT ON NEXT
PAGE

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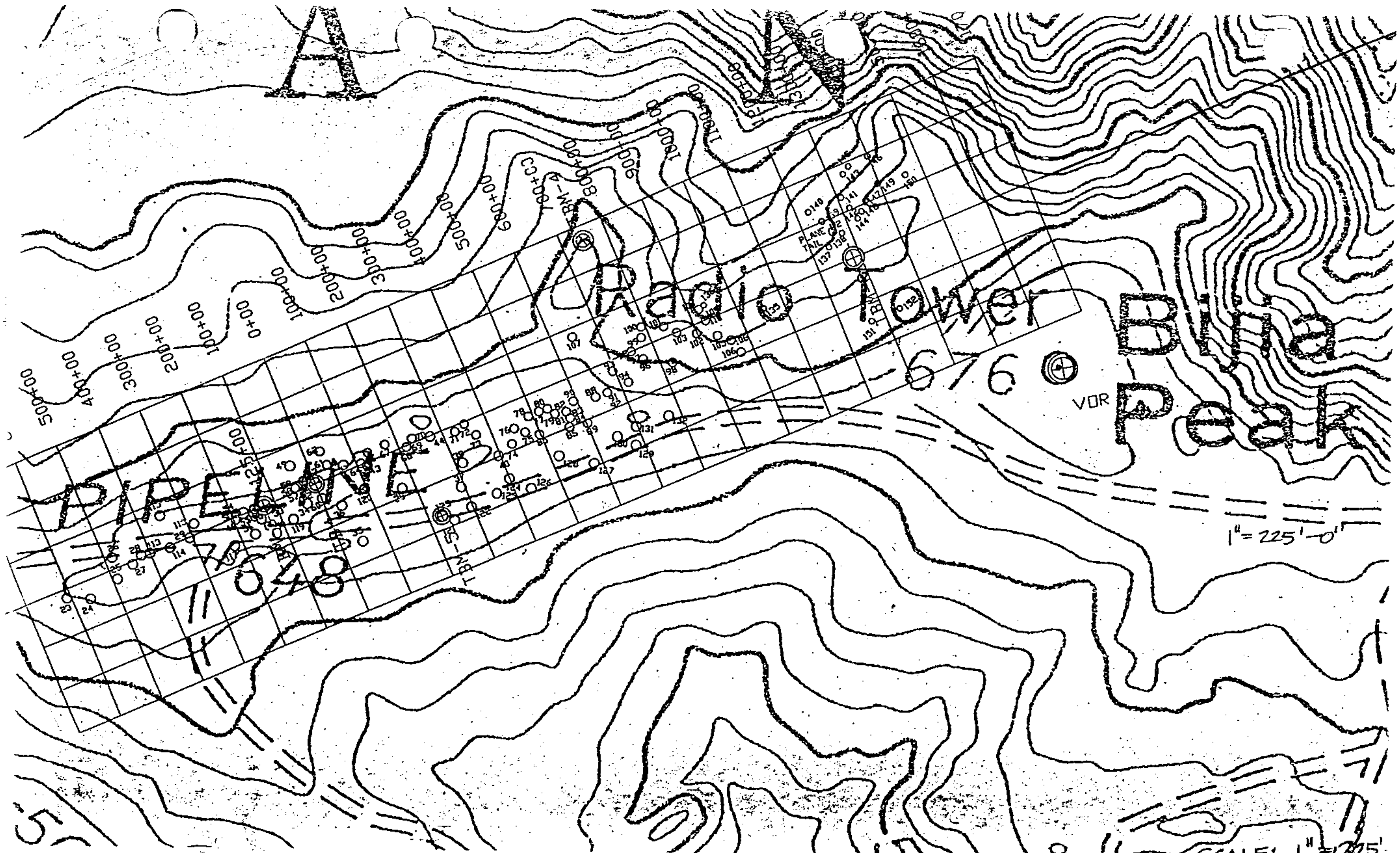
Radio Tower
Blue Peak
6760
VOR
PIPELINE
TBM-A
1" = 225'-0"
SCALE: 1" = 225'

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Attachment II

FAA Radar Data

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Due to Public Hearing Exhibit size limitations, the complete FAA radar data listing is provided in the public docket copy of this report.

Attachment III

Jeppesen Approach Plate Data

JEPPESEN (Korean) 2 AUG 96 11-1 HIGH ALT

AGANA, GUAM
GUAM INTL
ILS Rwy 6L
LOC 110.3 IGUM

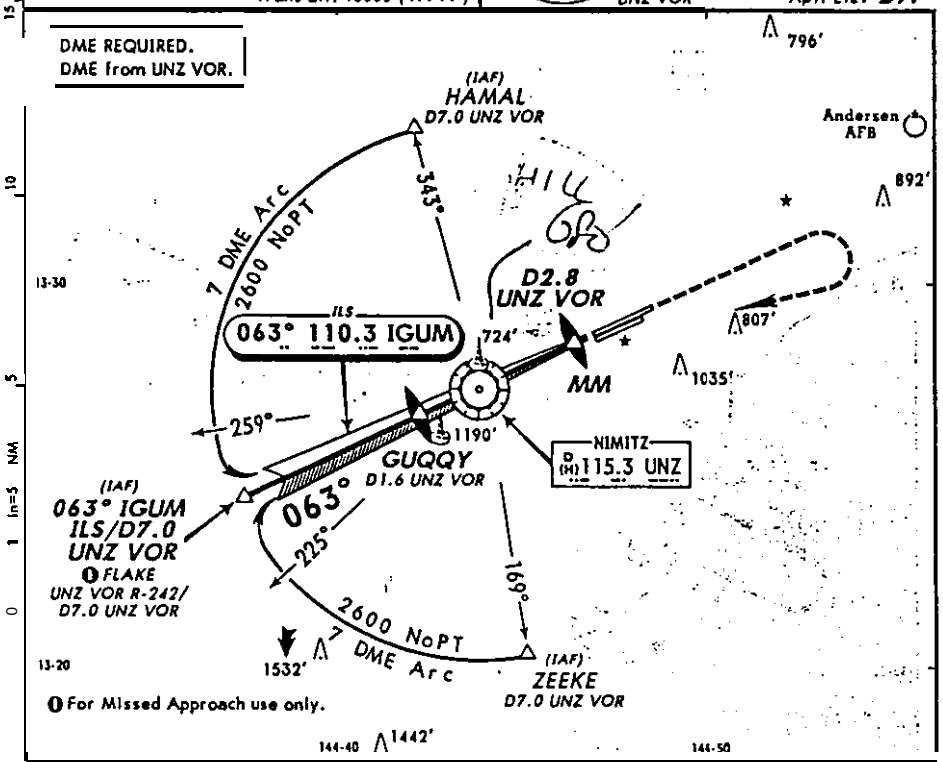
Apt. Elev 297'

ATIS 119.0
GUAM Approach (R) 119.8
AGANA Tower 118.1
Ground 121.9

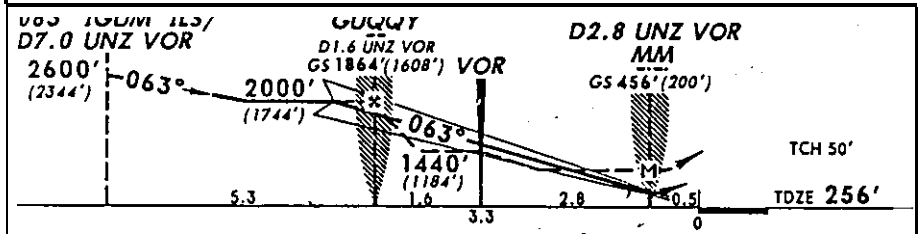
Alt Set: INCHES
Trans level: FL 180
Trans alt: 18000'(17744')

2200'
090° — 270°
2600'
MSA
UNZ VOR

DME REQUIRED.
DME from UNZ VOR.



For Missed Approach use only.



MISSED APPROACH: Climb to 2600, then turn RIGHT via UNZ VOR R-242 to FLAKE D7.0 UNZ VOR and hold SOUTHWEST, RIGHT turn, 062° inbound.

ILS		LOC (GS out)			CIRCLE-TO-LAND Not Authorized Southeast of Rwy 6R-24L	
DA(H) 456'(200')		MDA(H) 560'(304')				
LL	RAIL or ALS out		RAIL out	ALS out	Max Kts	MDA(H)
2	3/4	1/2	3/4	1	90	720' (423')-1
					120	760' (463')-1
					140	760' (463')-1 1/2
		3/4	1		165	860' (563')-2

Kts	70	90	100	120	140	160
GS 3.00°	377	484	538	646	753	861
MAP at D2.8 UNZ VOR or						

JEPPESEN (Korean) 2 AUG 96 13-2 HIGH ALT

AGANA, GUAM
GUAM INTL
VOR-A
VOR 115.3 UNZ

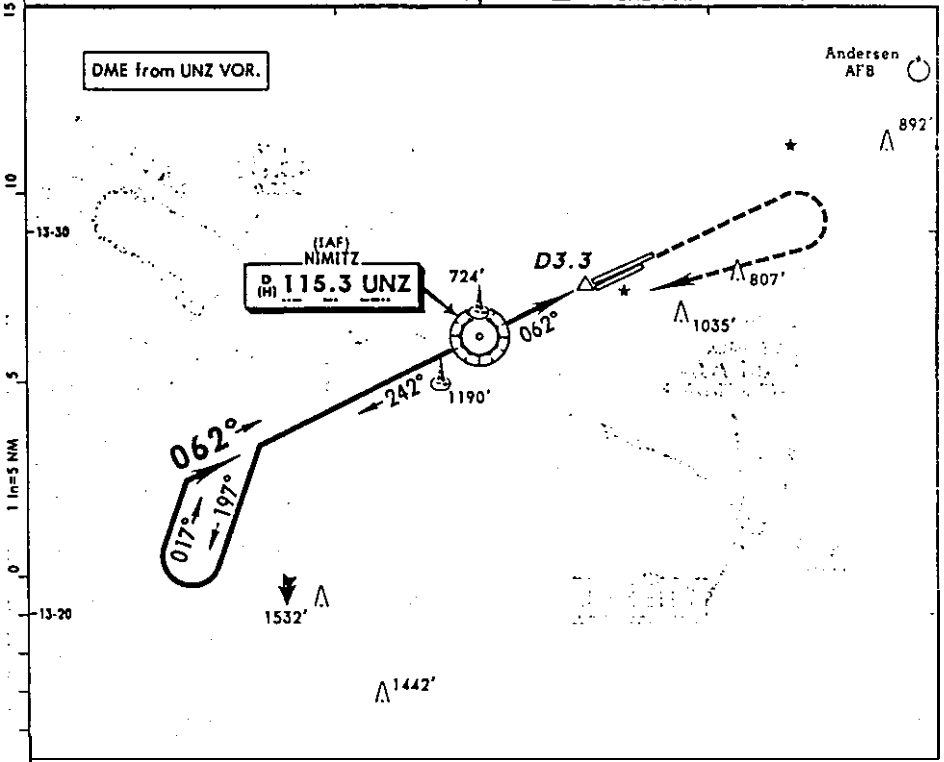
Apt. Elev. 297'

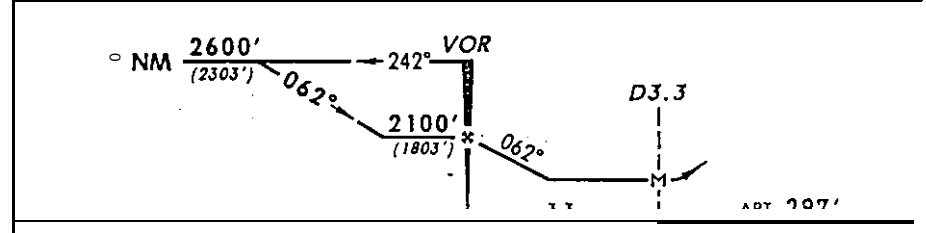
ATIS 119.0
GUAM Approach (R) 119.8
AGANA Tower 118.1
Ground 121.9

Alt Set: INCHES
Trans level: FL 180
Trans alt: 18000'(17744')

2200'
090° — 270°
2600'
MSA
UNZ VOR

DME from UNZ VOR.





MISSED APPROACH: Climb to 2600' then turn RIGHT direct UNZ VOR.

Not Authorized Southeast of Rwy 6R-24L

	Max	
B	120	780' (483')-1
C	140	780' (483')-1 1/2
D	165	860' (563')-2

Gnd speed-Kts	70	90	100	120	140	160
MAP at D3.3 or						

Attachment IV

Time-Correlated FDR and CVR Data

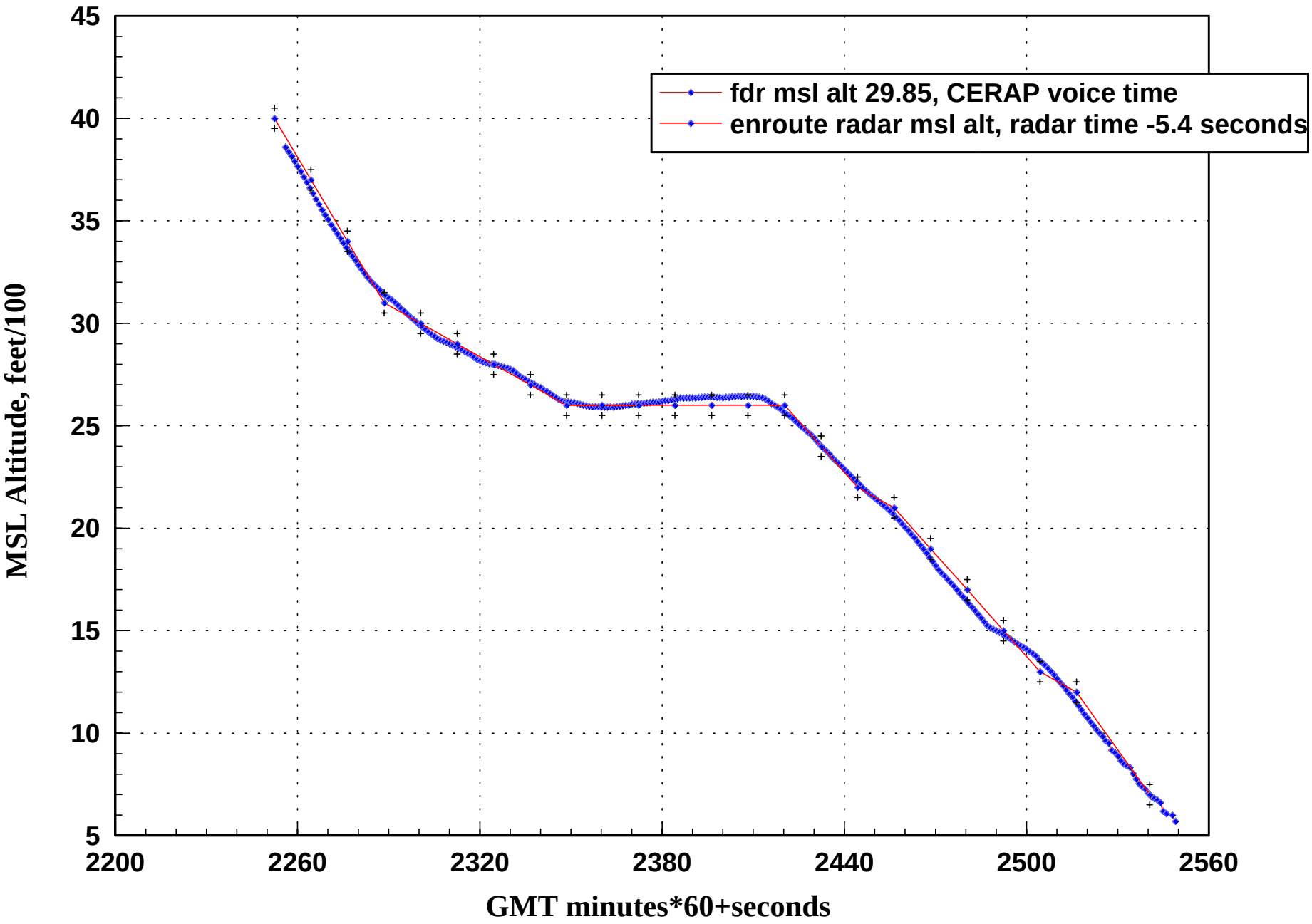
RDO-2 VHF Communications CVR-FDR Time Correlation, KAL801

CVR/ATC GMT for RDO-2 transmission	FDR Readout Elapsed Time for RDO-2 transmission	Time Offset
15:38:53	04:45:26	10:53:27
15:39:48	04:46:21	10:53:27
15:40:47	04:47:19	10:53:28
15:40:55	04:47:27	10:53:28
15:41:14	04:47:46	10:53:28

AVERAGE TIME OFFSET = 10:53:28

Therefore. add 10:53:28 to FDR readout elapsed times for correlation with CVR transcript.

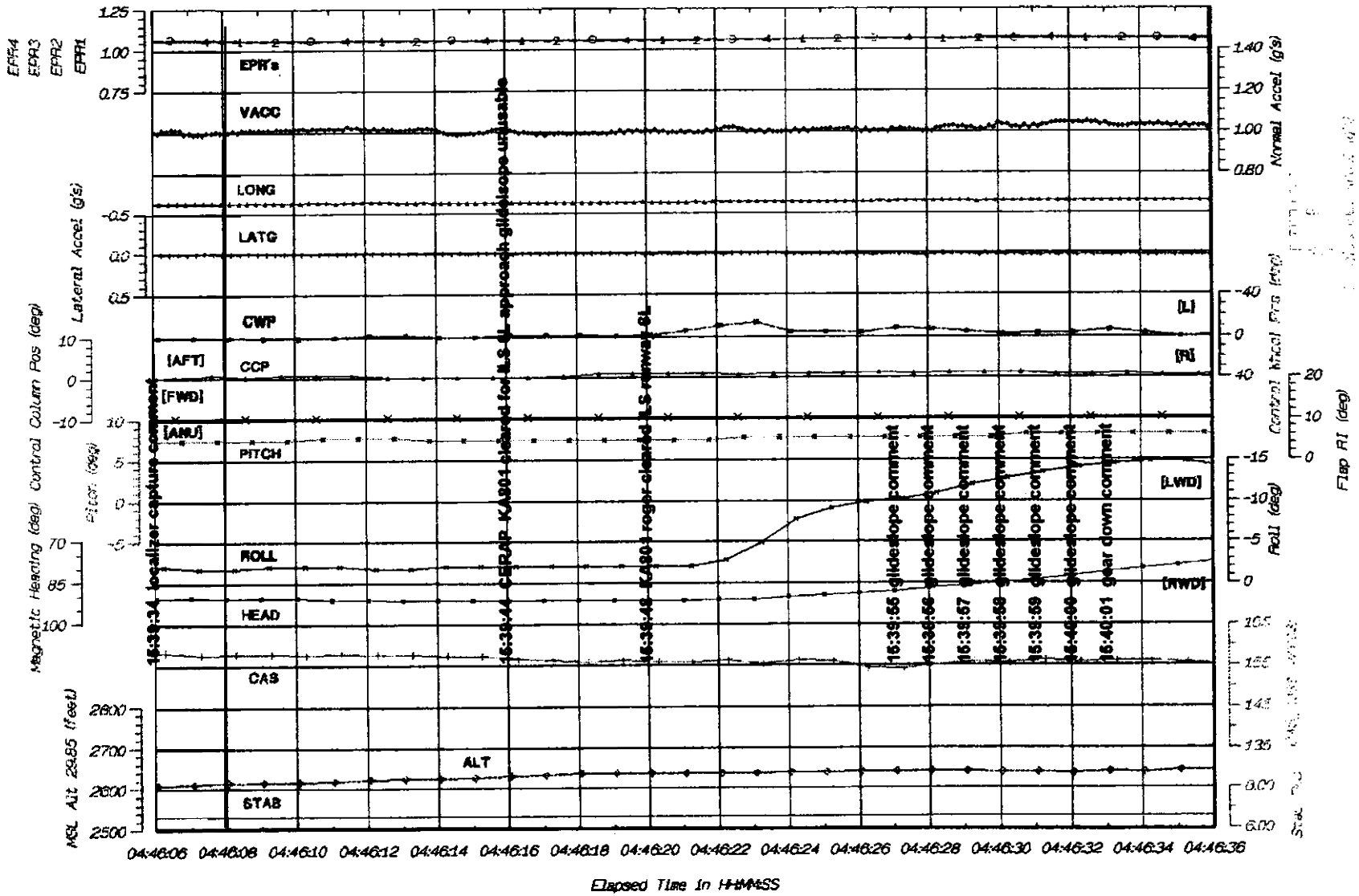
KAL 801 FDR MSL ALTITUDE (29.85 in Hg) vs. TIME



The following plots do not show verbatim CVR excerpts. Copies with verbatim CVR excerpts will be provided after the CVR transcript is placed in the public docket.

KAL Fligh 801

August 5, 1997 NTSB # DCA-97-MA-058



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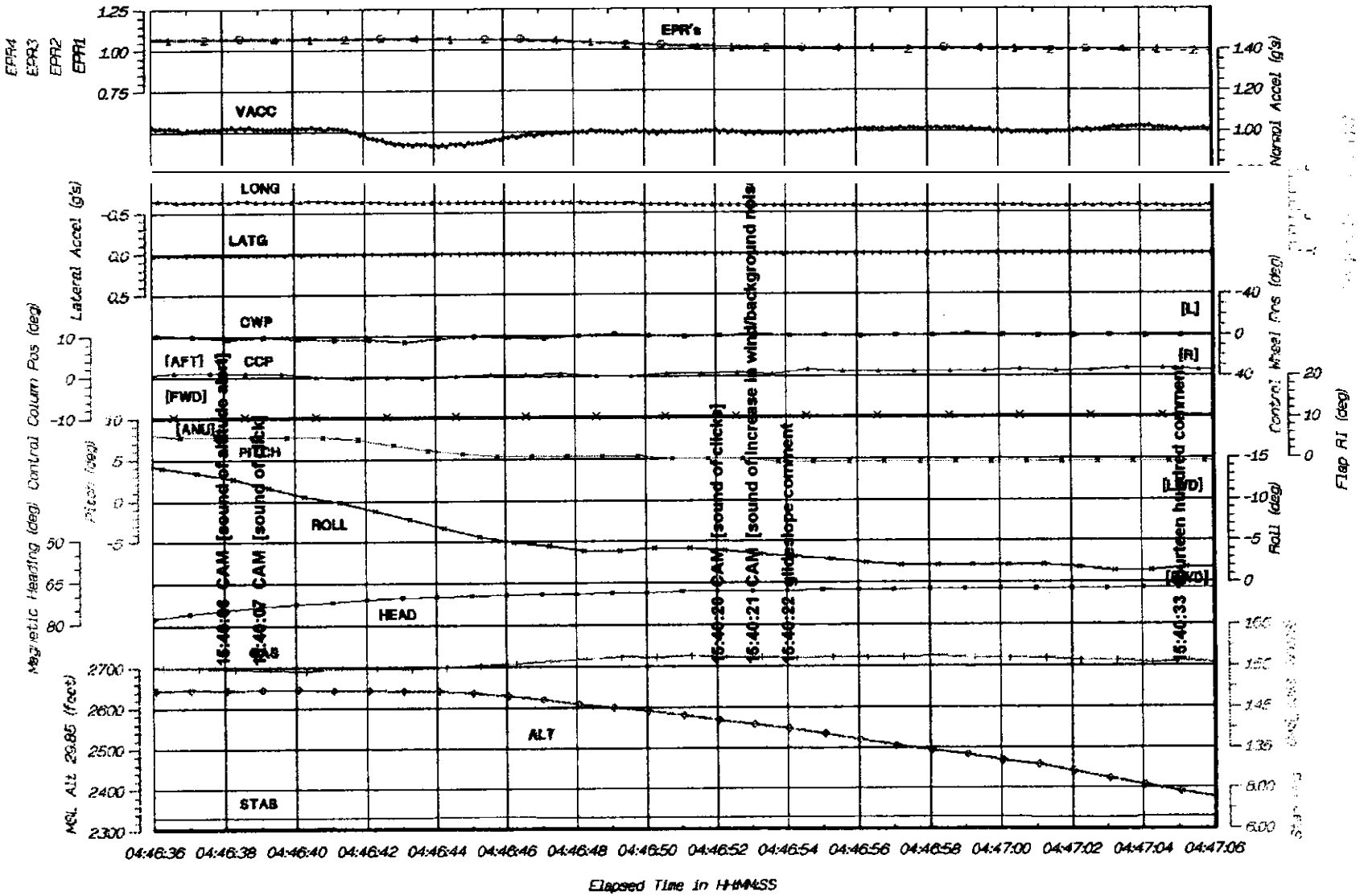
Plot CP6, Recovery 1

NTSB Flight Recorder Laboratory

KAL Flight 801

August 5, 1997

NTSB # : DCA-97-MA-058



Plot CP5, Recovery 1

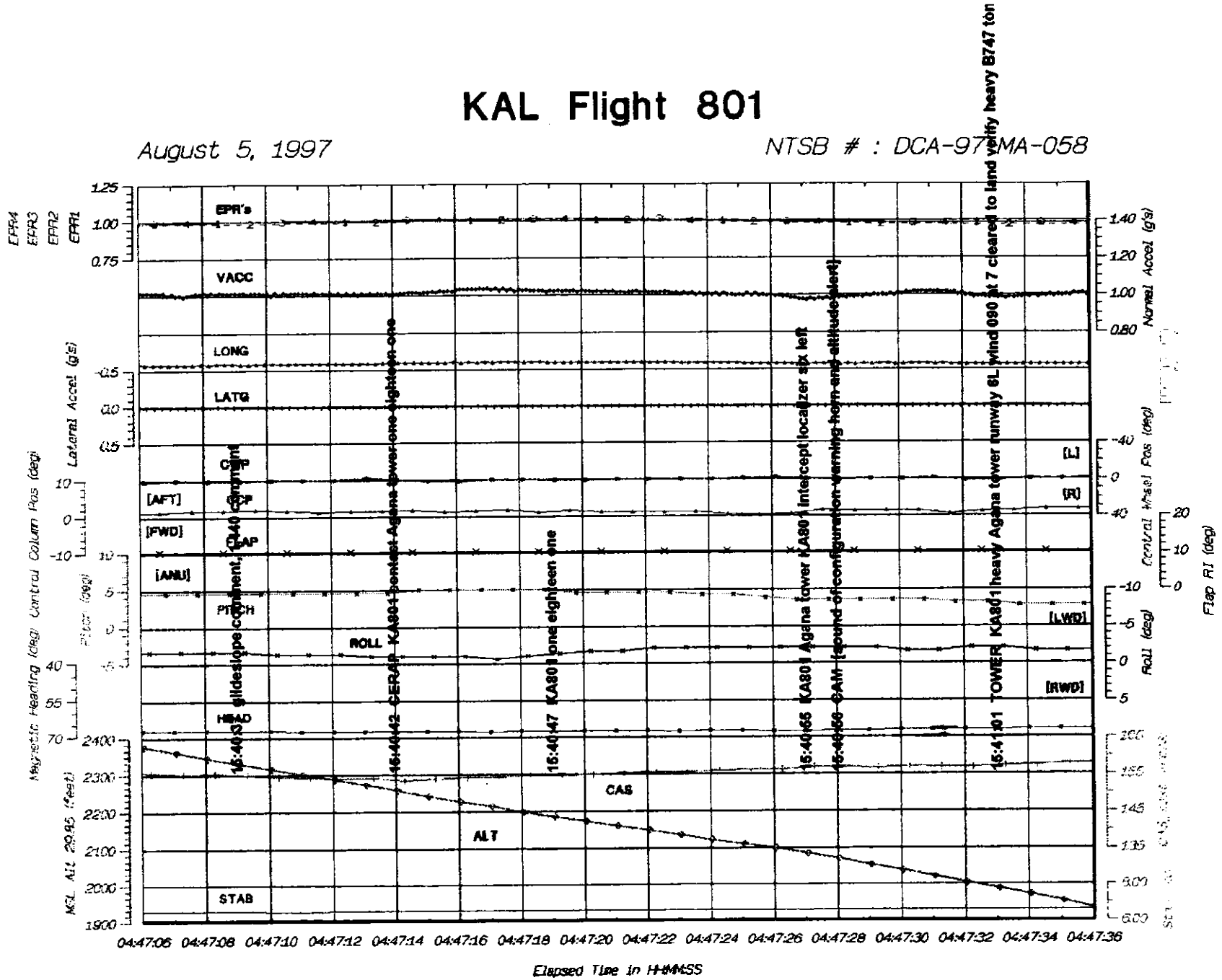
NTSB Flight Recorder Laboratory

02

KAL Flight 801

August 5, 1997

NTSB # : DCA-97MA-058



Plot CP4, Recovery 1

NTSB Flight Recorder Laboratory

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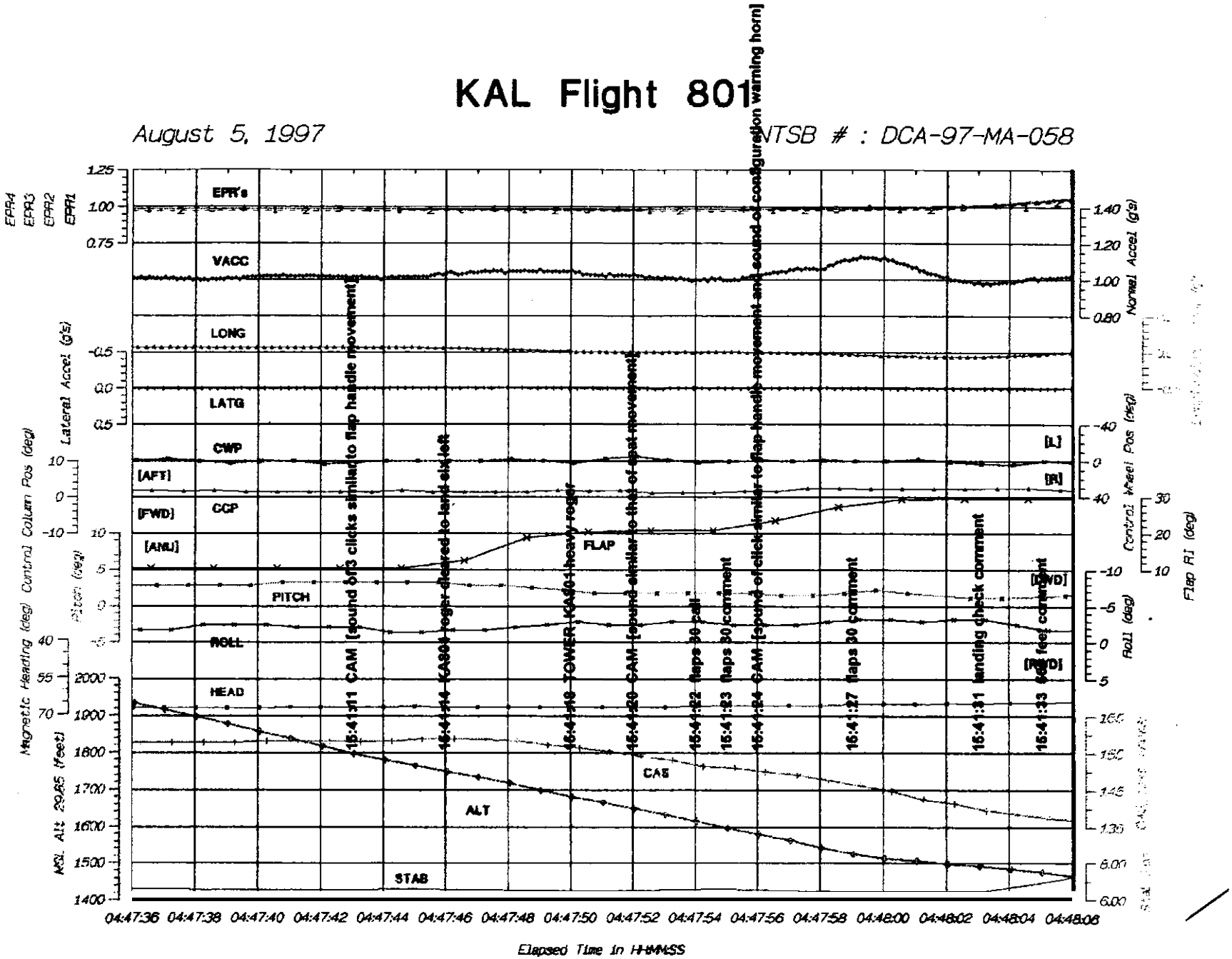
KAL Flight 801

August 5, 1997

NTSB # : DCA-97-MA-058



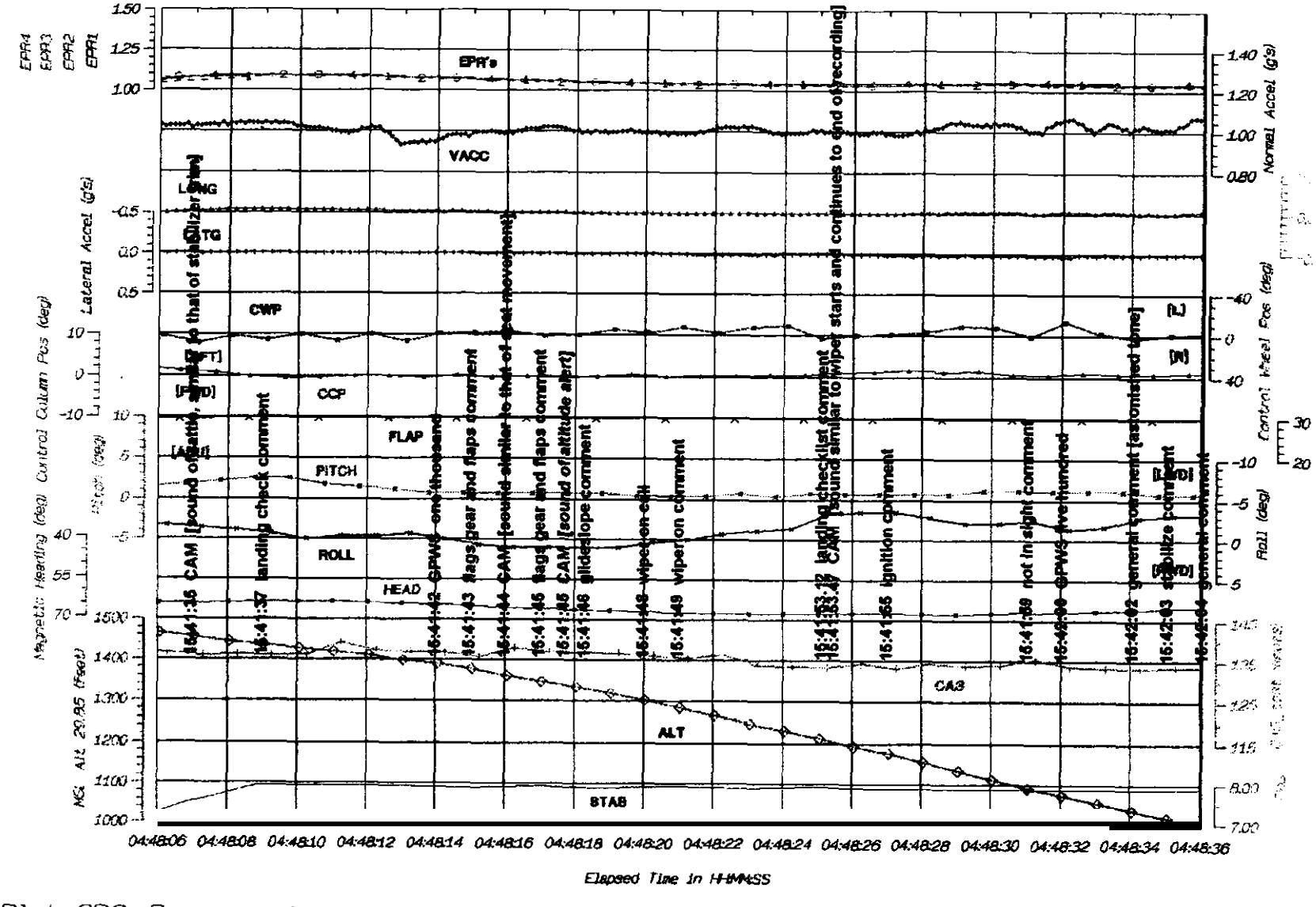
Plot CP3, Recovery 1

NTSB Flight Recorder Laboratory

KAL Flight 801

August 5, 1997

NTSB # DCA-97-MA-058



Plot CP2, Recovery 1

NTSB Flight Recorder Laboratory

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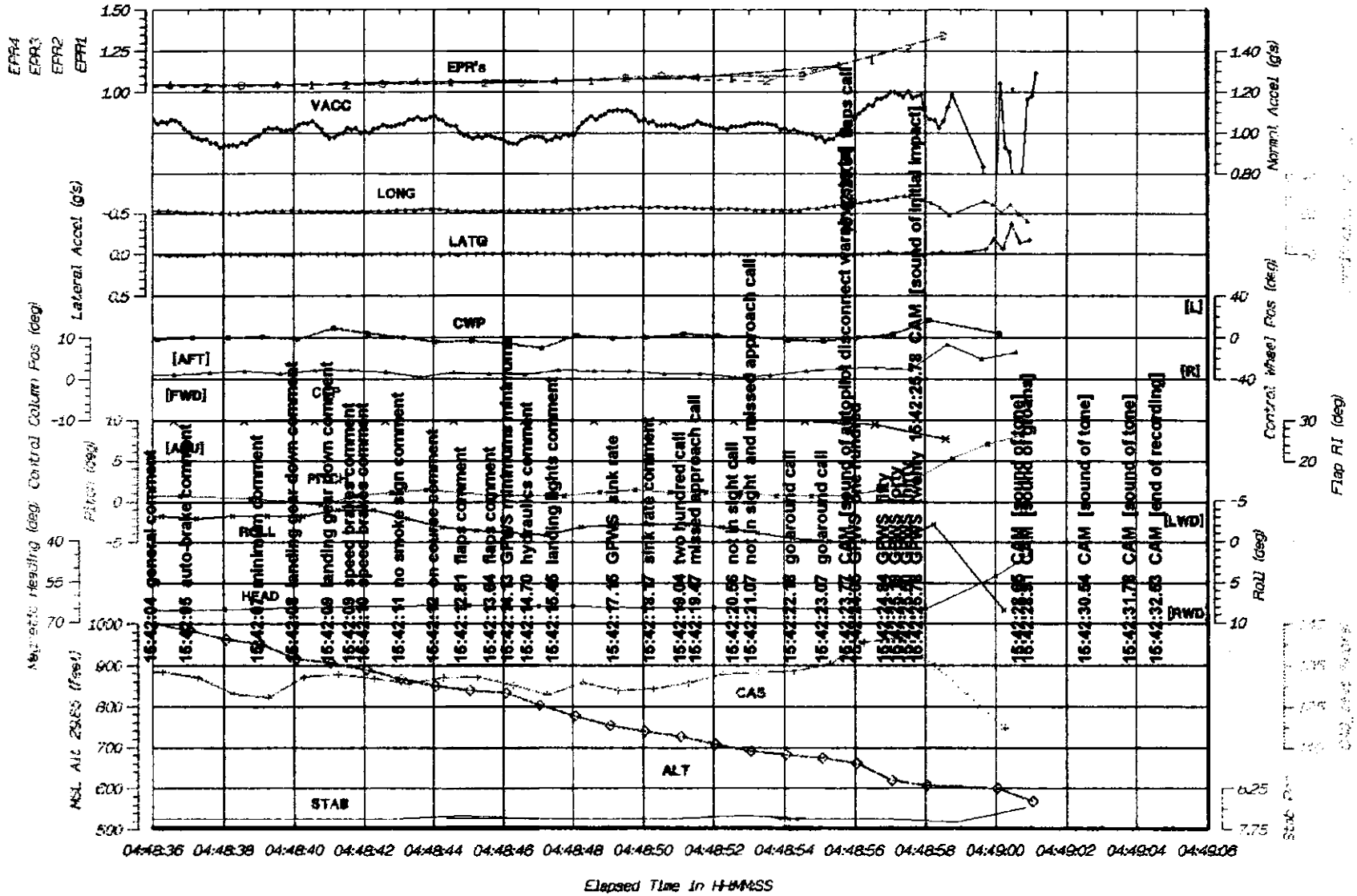
KAL Flight 801

August 5, 1997 NTSB # : DCA-97-MA-058



Plot CP1, Recovery 1

NTSB Flight Recorder Laboratory

Attachment V

Terrain Elevation Data

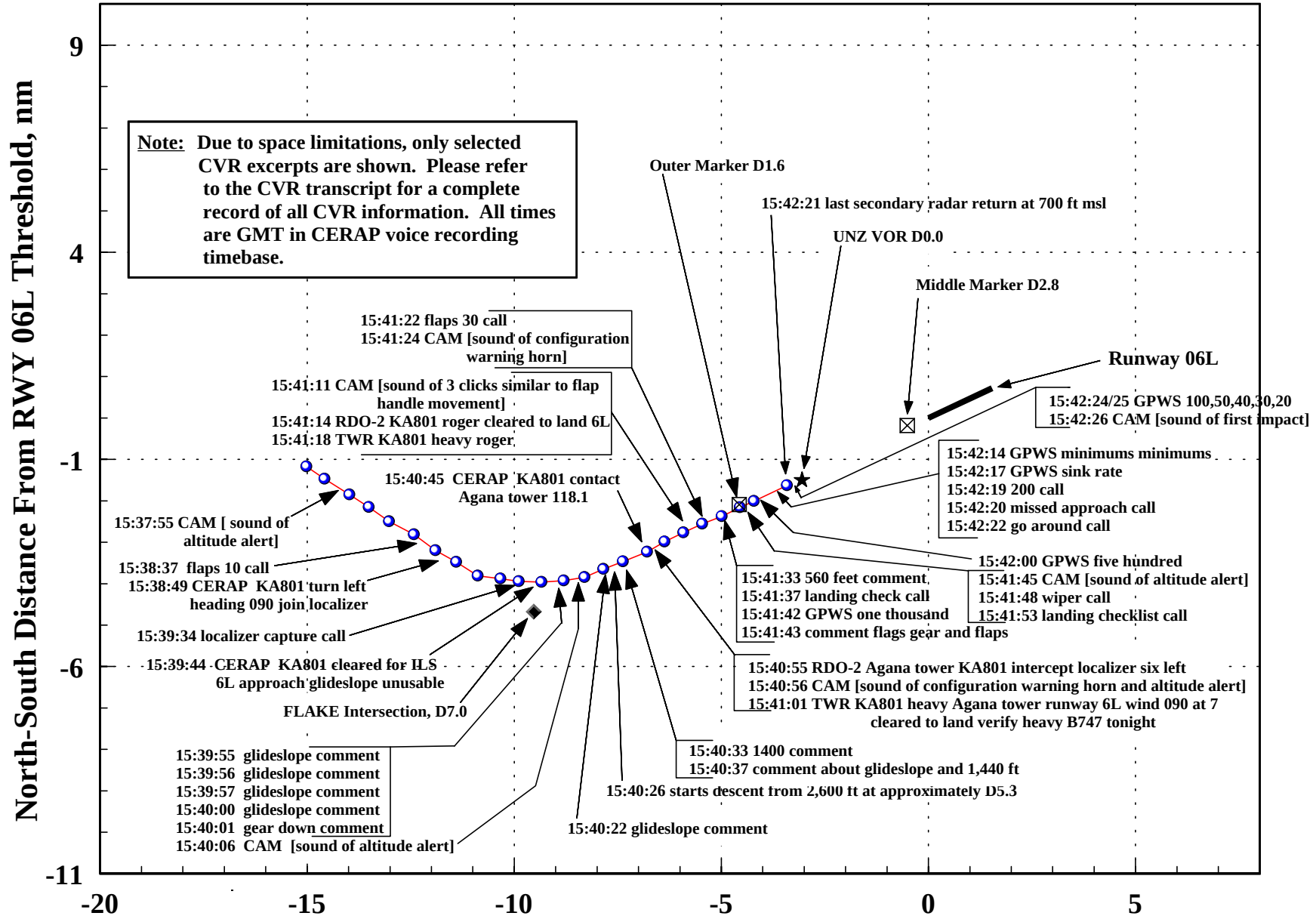
Due to Public Hearing Exhibit size limitations, the terrain elevation data set is provided in the public docket copy of this report.

Attachment VI

Plan and Profile Views
of Radar Data, Approach Plate Data, Terrain Elevation Data, and CVR Information

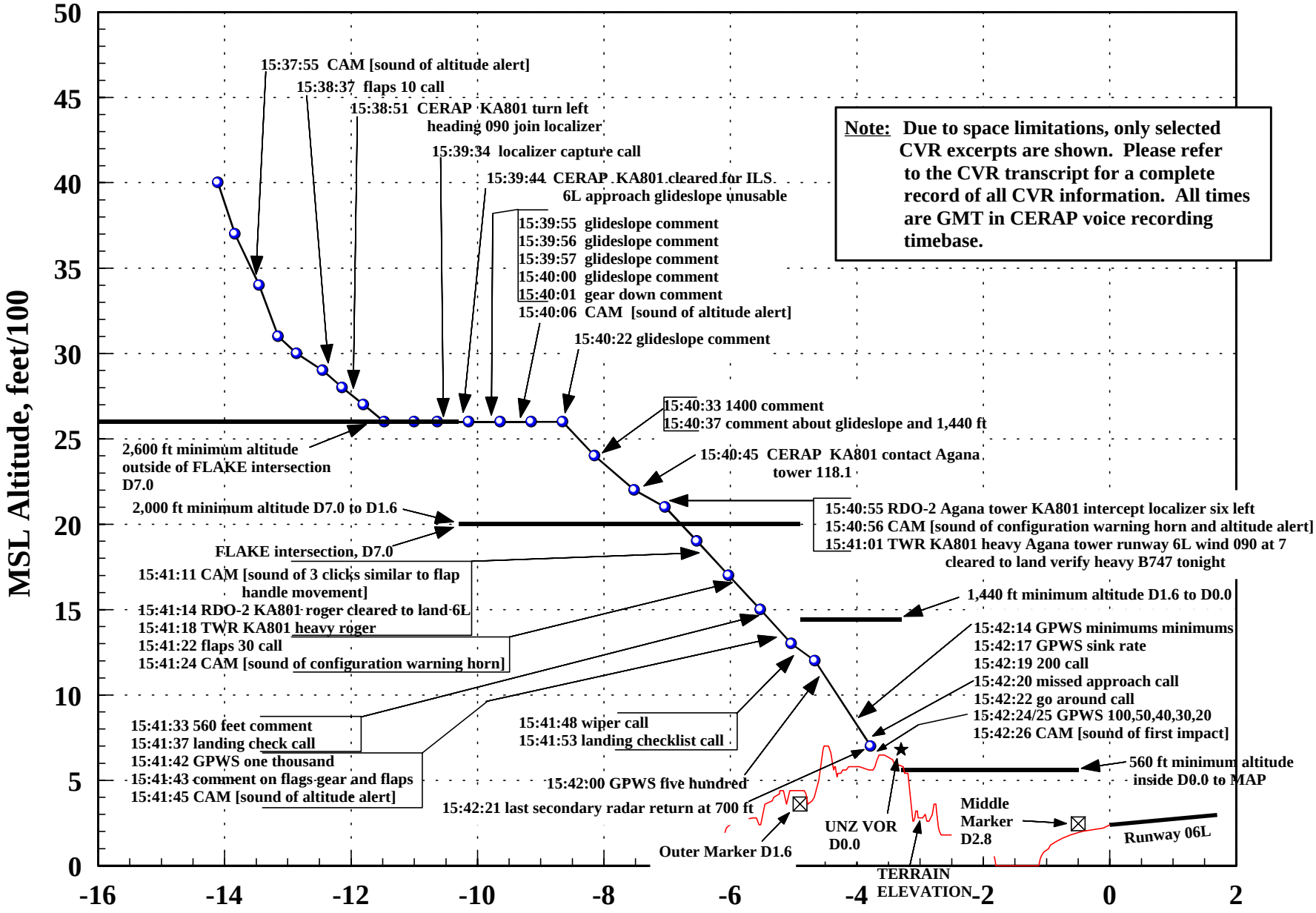
The following plots do not show verbatim CVR excerpts. Copies with verbatim CVR excerpts will be provided after the CVR transcript is placed in the public docket.

Korean Airlines B747-300 At Guam, 8/6/97
Overhead View Of FAA Radar Data With Selected ATC And CVR Communication Excerpts



CP
NTSB, RE-60

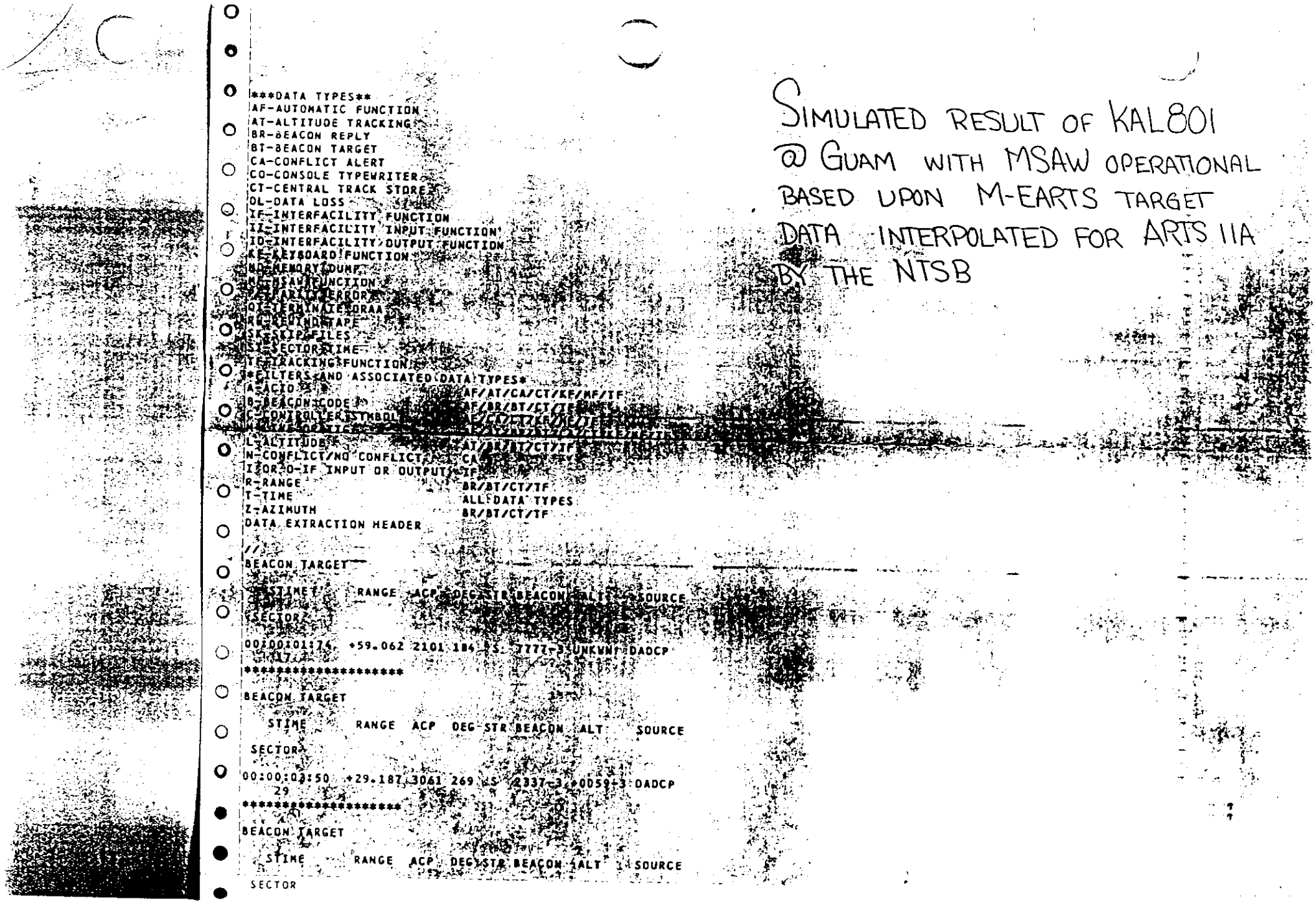
Korean Airlines B747-300 At Guam, 8/6/97
Side View Of FAA Radar Data With Selected ATC And CVR Communication Excerpts



CP
NTSB, RE-60

Attachment VII

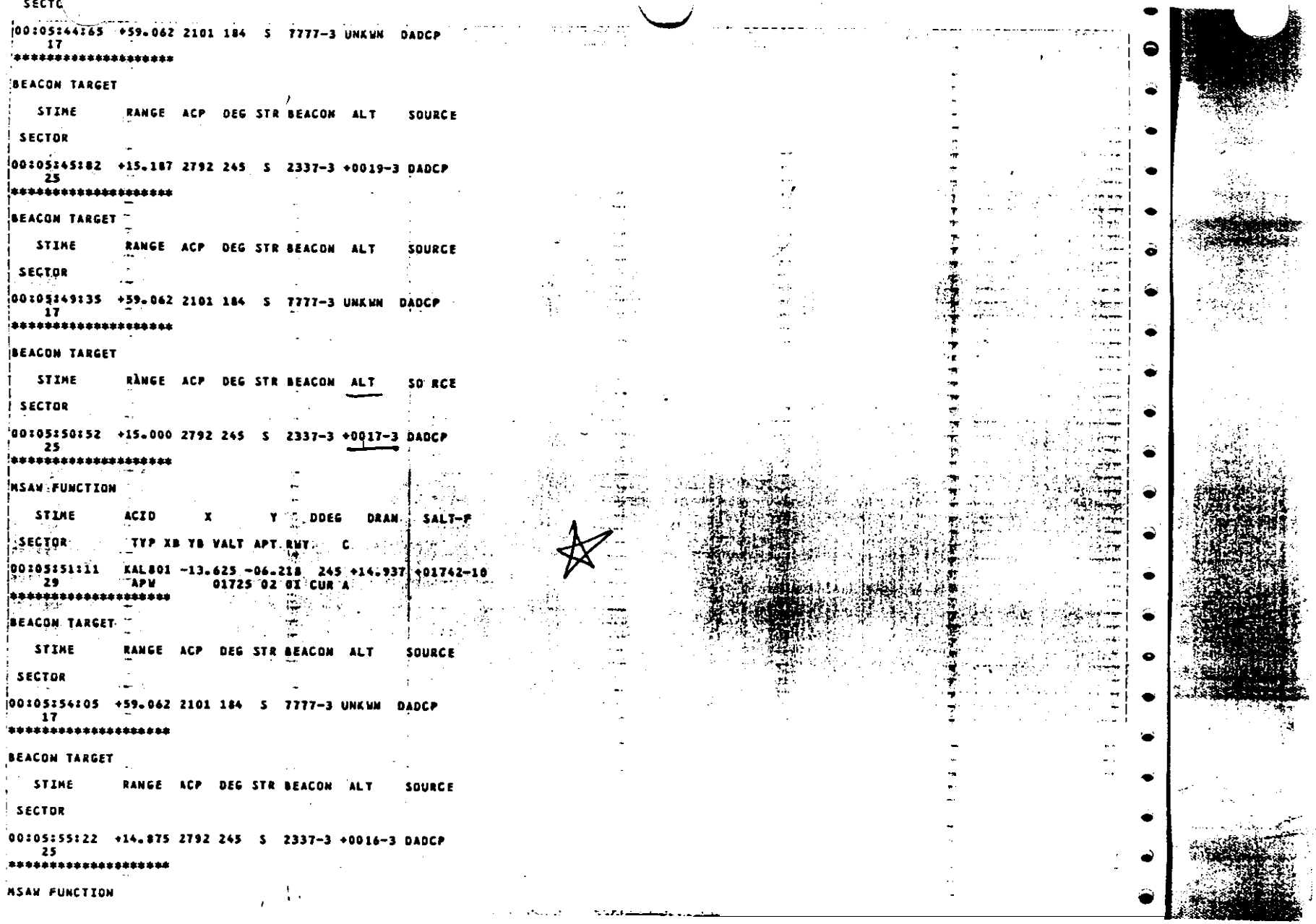
MSAW Simulation Data



```
***DATA TYPES**
AF-AUTOMATIC FUNCTION
AT-ALTITUDE TRACKING
BR-BEACON REPLY
BT-BEACON TARGET
CA-CONFLICT ALERT
CO-CONSOLE TYPEWRITER
CT-CENTRAL TRACK STORE
DL-DATA LOSS
IF-INTERFACILITY FUNCTION
II-INTERFACILITY INPUT FUNCTION
IO-INTERFACILITY OUTPUT FUNCTION
KE-KEYBOARD FUNCTION
MD-MEMORY DUMP
MF-MSAW FUNCTION
PE-PARITY ERROR
TA-TERMINATE DRAA
RW-REWIND TAPE
SK-SKIP FILES
SS-SECTOR TIME
TF-TRACKING FUNCTION
**FILTERS AND ASSOCIATED DATA TYPES*
A-ACID                          AF/AT/CA/CT/KE/MF/TF
B-BEACON CODE                   AF/BR/BT/CT/TF
C-CONTROLLER ISTNBOL            AF/AT/CT/KE/DL/TF
H-HOLD CONFLICT                 CA
L-ALTITUDE                      AT/BR/BT/CT/TF
N-CONFLICT/NO CONFLICT          CA
I-OR O-IF INPUT OR OUTPUT       IF
R-RANGE                         BR/BT/CT/TF
T-TIME                          ALL DATA TYPES
Z-AZIMUTH                       BR/BT/CT/TF
DATA EXTRACTION HEADER

//
BEACON TARGET
   STIME      RANGE  ACP  DEG STR BEACON  ALT    SOURCE
 SECTOR
00:00:01:14  +59.062 2101 184 ES  7777-3 UNKWN DADCP
     17
********************
BEACON TARGET
   STIME      RANGE  ACP  DEG STR BEACON  ALT    SOURCE
 SECTOR
00:00:03:50  +29.187 3061 269 ES  0337-3 +0059+3 DADCP
     29
********************
BEACON TARGET
   STIME      RANGE  ACP  DEG STR BEACON  ALT    SOURCE
 SECTOR
```

SIMULATED RESULT OF KAL801 @ GUAM WITH MSAW OPERATIONAL BASED UPON M-EARTS TARGET DATA INTERPOLATED FOR ARTS IIA BY THE NTSB



SECTC

00:05:44:65 +59.062 2101 184 S 7777-3 UNKWN DADCP
17
****

BEACON TARGET

STIME RANGE ACP DEG STR BEACON ALT SOURCE
SECTOR

00:05:45:82 +15.187 2792 245 S 2337-3 +0019-3 DADCP
25
****

BEACON TARGET

STIME RANGE ACP DEG STR BEACON ALT SOURCE
SECTOR

00:05:49:35 +59.062 2101 184 S 7777-3 UNKWN DADCP
17
****

BEACON TARGET

STIME RANGE ACP DEG STR BEACON ALT SO RCE
SECTOR

00:05:50:52 +15.000 2792 245 S 2337-3 +0017-3 DADCP
25
****

MSAW FUNCTION

STIME ACID X Y DDEG DRAN SALT-F
SECTOR TYP XB YB VALT APT RWY C

00:05:51:11 KAL801 -13.625 -06.218 245 +14.937 +01742-10
29 APW 01725 02 01 CUR A
****

BEACON TARGET

STIME RANGE ACP DEG STR BEACON ALT SOURCE
SECTOR

00:05:54:05 +59.062 2101 184 S 7777-3 UNKWN DADCP
17
****

BEACON TARGET

STIME RANGE ACP DEG STR BEACON ALT SOURCE
SECTOR

00:05:55:22 +14.875 2792 245 S 2337-3 +0016-3 DADCP
25
****

MSAW FUNCTION

Attachment VI

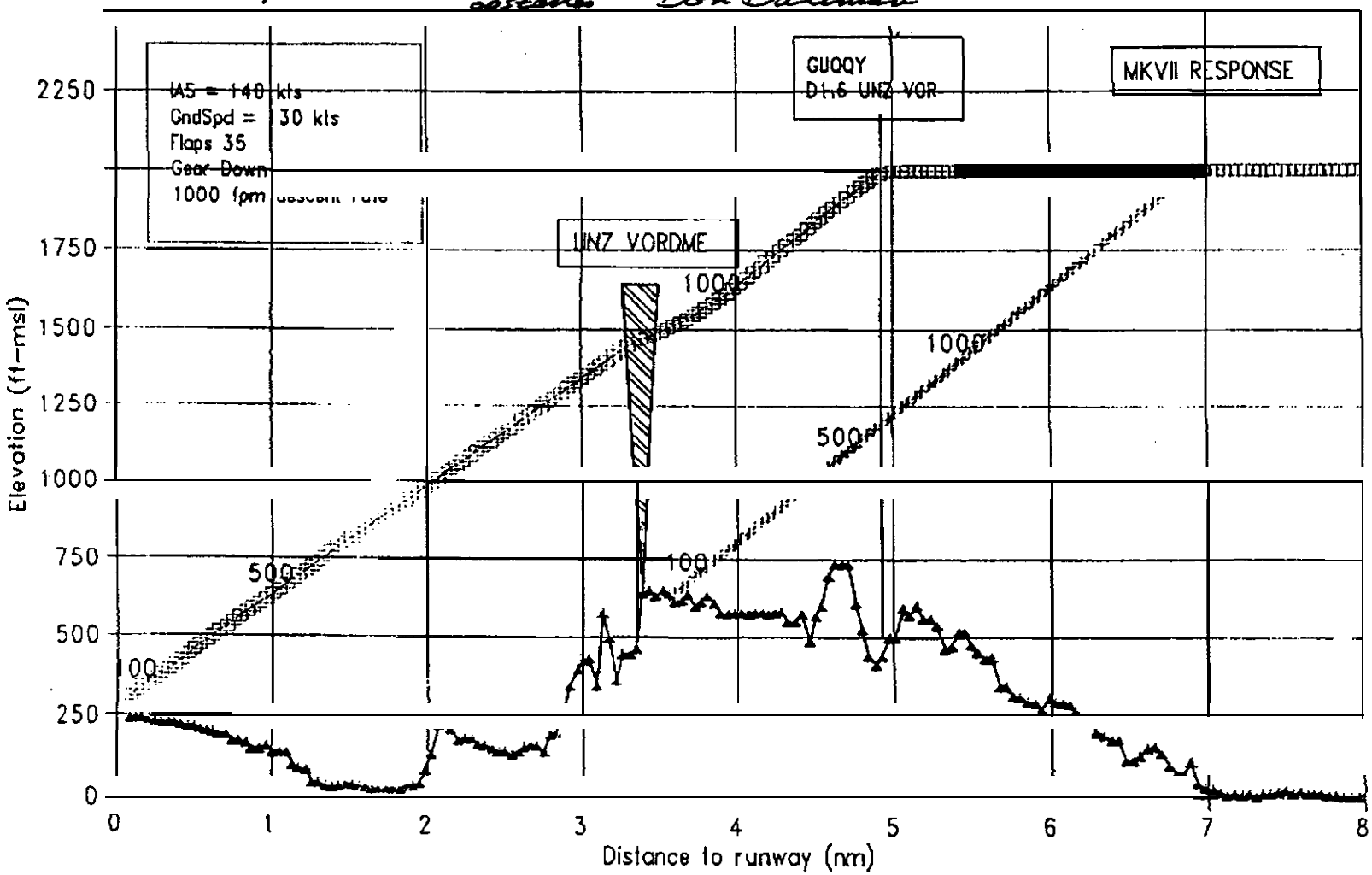
GPWS and EGPWS Simulation Data

The following GPWS/EGPWS simulation data were performed by AIlied Signal prior to their obtaining radar and other data for this accident from the NTSB. Therefore, these data are preliminary and do not accurately reflect the flight path and warning times. Updated simulation results based on NTSB radar and other data for K A 8 0 will be provided as soon as they become available. However, the warning times and types of warnings shown here are expected to closely approximate the updated simulation results.

(1) This is a revised plot of the terrain along the localizer ℄. (The first earlier plot was along the VOR course.) 3 arc second data base was used.

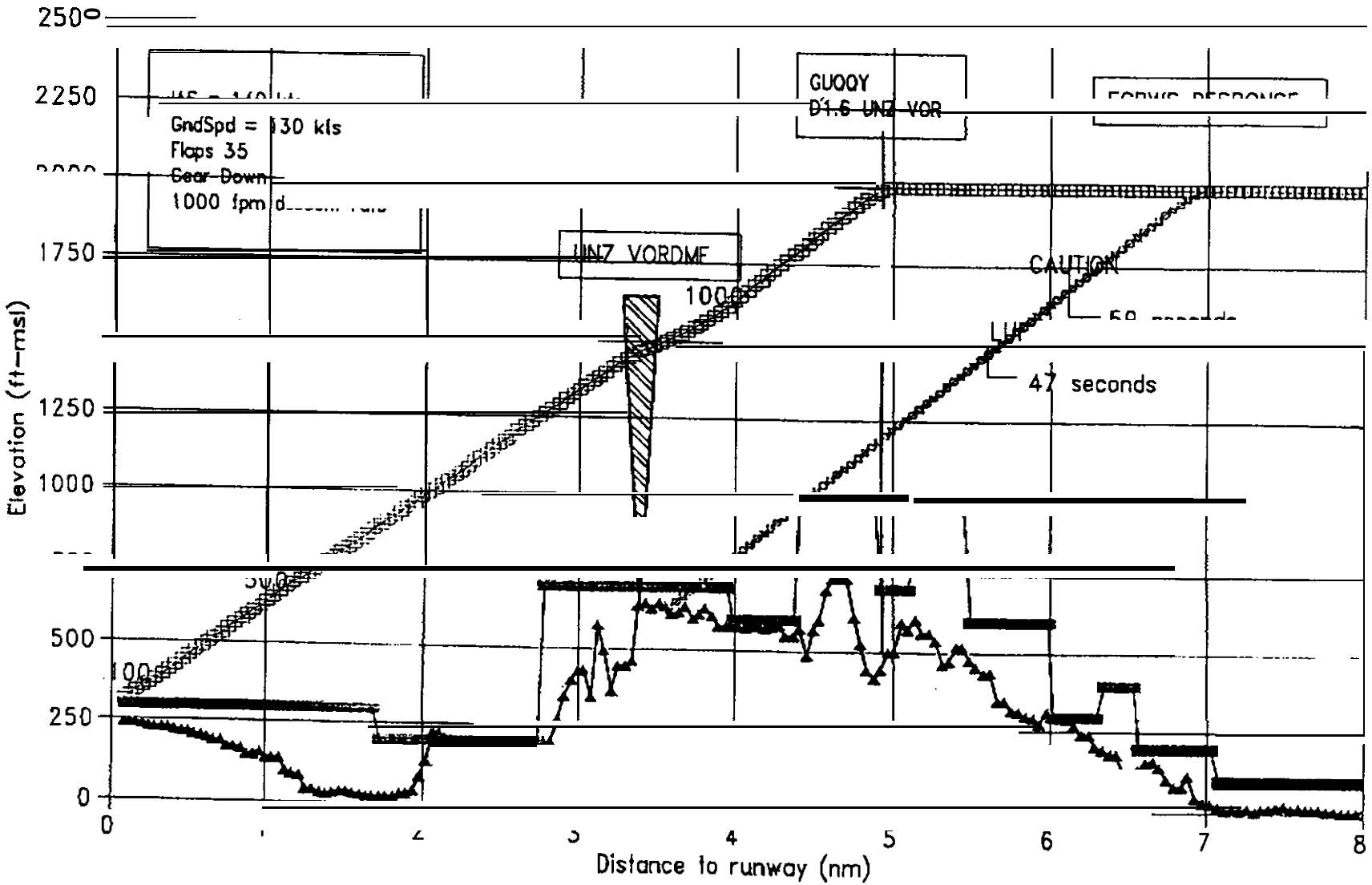
(2) Page 2 is the E-GPWS using both obstacles and terrain. Page 3 is the terrain data used in E-GPWS along with the towers or obstacles

B747-300 Accident – Guam
August 8, 1997
Don Bateman



★ PRELIMINARY SIMULATION – REVISED SIMULATION TO FOLLOW. ★

B747-300 Accident – Guam
August 8, 1997



☆ PRELIMINARY SIMULATION – REVISED SIMULATION TO FOLLOW. ☆