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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT BRUSSELS--ETC(U)
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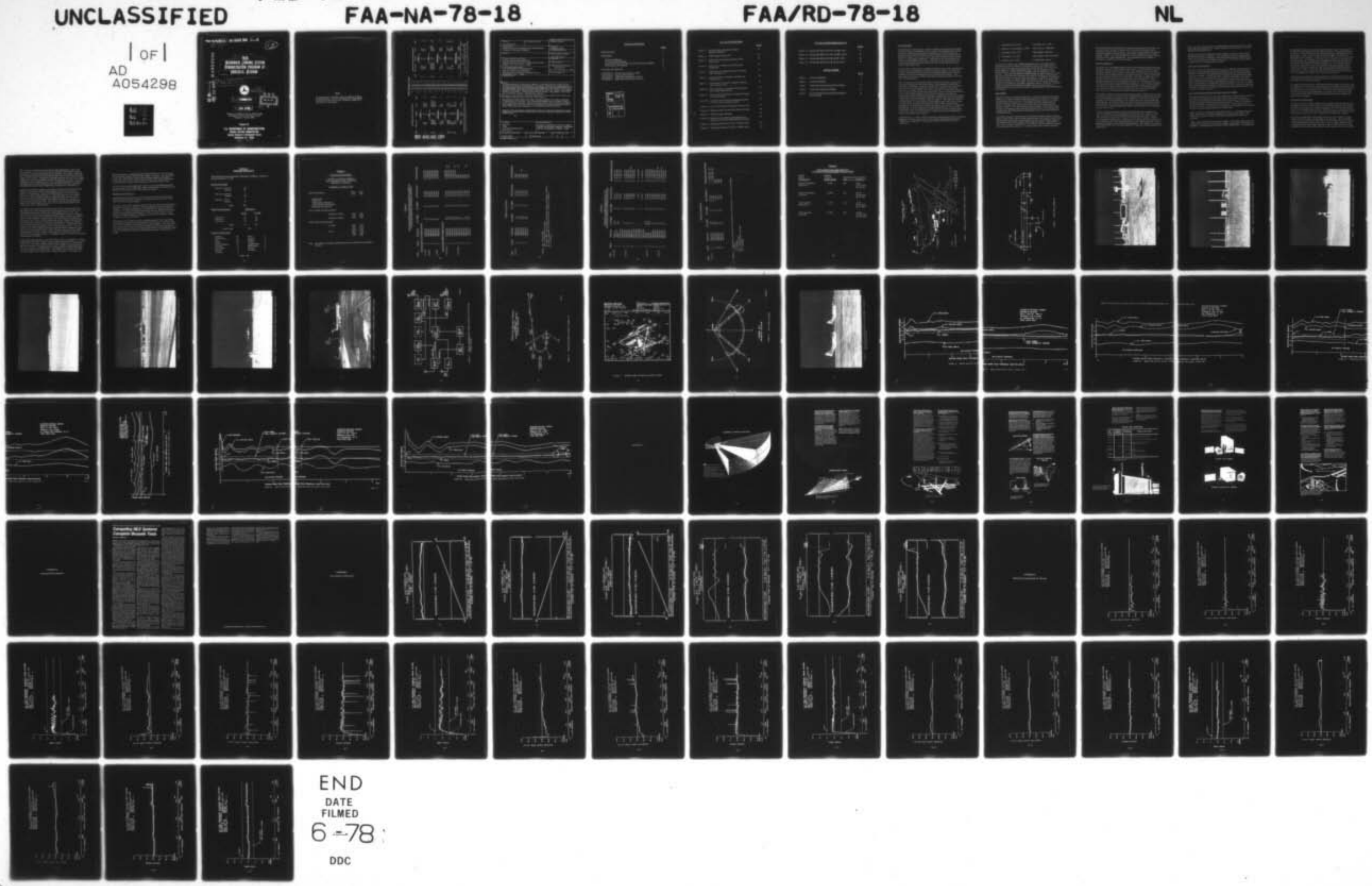

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Report No. FAA/RD-78-18 FOR FURTHER TRAN

TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT BRUSSELS, BELGIUM.

FAA-NA-78-18

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FEBRUARY 1978

FINAL REPORT.

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

240 550

NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

TECHNICAL REPORT STANDARD TITLE PAGE

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16. Abstract

The demonstrations at Brussels, Belgium, were the sixth in a series of FAA conducted operational demonstrations of several TRSB system configurations at selected airports in the United States and abroad. Previous demonstrations were accomplished at Cape May County Airport, Cape May, New Jersey, USA; Jorge Newbery Aeroparque, Buenos Aires, Argentina; Toncontin Airport, Tegucigalpa, Honduras; and John F. Kennedy International Airport, Long Island, New York, USA; and Kjevik Airport, Kristiansand, Norway.

The Basic Wide aperture TRSB was installed to service Runway 07L which was the longest of three major runways at the airport.

Operational demonstrations and data acquisition flights were made using FAA CV-880 and B-727 aircraft. One-third of the landings were autoland. Flight profiles included straight-in and curved approaches, radials, and partial orbits. Some flight tests were also made by British Civil Aviation Authority personnel using TRSB equipment installed in a CAA flight inspection aircraft.

Results of the operational demonstrations indicate that the performance of the TRSB Basic Wide system configuration meets the ICAO "full capability system" requirements.

17. Key Words Brussels TRSB Aircraft Landing System Basic Wide	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and Australian (INTERSCAN) candidate submission to the International Civil Aviation Organization (ICAO) as the future all-weather landing system which would replace ILS.

In March 1977, following a 15-month period of intensive and comprehensive assessment of all competing microwave landing systems, the ICAO All Weather Operations Panel (AWOP) recommended TRSB as the preferred candidate microwave landing system for international adoption. This assessment involved more than 100 leading international experts in microwave landing systems.

The Air Navigation Commission (ANC) reviewed the AWOP recommendation and forwarded it to the ICAO Council, whereupon the Council has scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing system to eventually replace ILS. In the interim, in consonance with the ICAO Council suggestion that proposing States carry out system demonstrations at operational airports, the FAA has developed a program to demonstrate several TRSB MLS hardware configurations at selected airports in the United States and abroad. (Hereafter in this document for simplicity, "TRSB MLS" will be referred to only as "TRSB.") The objective of these demonstrations is to show that the TRSB signal format and system design are mature and satisfy the full range of requirements, from general aviation use to scheduled air carrier operations, for Catetory I to Category III autoland. A further objective of these demonstrations is to provide opportunities for representatives and officials of the international aviation community to gain direct knowledge of TRSB and assess its applicability to their particular requirements.

On February 1, 2, and 3, 1978, at Zaventem International Airport, Brussels, Belgium, the sixth in this series of operational flight demonstrations of TRSB was accomplished. Previous operational demonstrations were conducted:

1. September 28-30, 1977 Cape May, N.J., USA

2. October 31 to November 4, 1977 Buenos Aires, Argentina

3. November 24-25, 1977 Tegucigalpa, Honduras

4. December 5-13, 1977 JFK Airport, New York, USA

5. January 23-24, 1978 Kristiansand, Norway

As in previous efforts, the TRSB demonstrations at Zaventem Airport afforded area aviation officials and technical experts the opportunity to observe and participate in presentations, ground system site tours, and actual flights in a TRSB-equipped aircraft. For the purpose of these demonstrations, Runway 07L was equipped with the TRSB Basic Wide System. Demonstration flights included straight-in approach paths, curved approaches and automatic landings as examples of airport arrival flight patterns that may be required in the near future. In addition, fixed radials and partial orbits were flown within the approach range of the airport for checking performance of the TRSB. Concurrently, the Small Community TRSB was installed and operated at Gosselies Airport, Charleroi, Belgium. Flight demonstrations included the TRSB systems at both airports. A separate document provides the details of the installation and demonstrations at Charleroi.

DISCUSSION

Zaventem Airport, situated 8 kilometers (5 miles) northeast of Brussels, Belgium, is a large national airport operated under control of the Belgian Government's Regie des Voies Aeriennes (RVA) (see Figure 1). As the principal airport of Belgium, it is the focal point for international air traffic, including many commercial airline and considerable general aviation aircraft. It is also shared with the military. It has three major runways, the longest of which exceeds 3638 meters (11,933 feet) and was equipped with the TRSB approach and landing system during the period of its demonstration.

The TRSB equipment demonstrated at Zaventem National Airport was the Phased Array Basic Wide Testbed manufactured by the Bendix Corporation's Communications Division in accordance with FAA specifications which are comparable to the ICAO (AWOP) "full capability system" requirements. This system design is intended for use in large, heavily trafficked airports. It incorporates beamwidths of 1° in both azimuth and elevation antennas.

It provides guidance throughout ± 60 degrees azimuth either side of the runway centerline, and from 1-degree up to 20-degrees elevation out to a range of at least 20 nautical miles. Precision L-Band Distance Measuring Equipment (DME) provides ranging information throughout the coverage volume. Figure 1 is a general plan view of the airport showing the relative locations of the TRSB installations. General information on TRSB is presented in Appendix A to this document.

System Installation

A survey team, including Federal Aviation Administration (FAA) and Regie des Voies Aeriennes (RVA) Belgiam personnel, visited propsective sites at Zaventem Airport on December 7, 1977. The TRSB system was sited on the same concrete pads as those occupied by the British microwave landing system during its demonstration some months earlier. Figure 2 shows the specific siting on Runway 07L at Zaventem. The azimuth subsystem was located 167 meters (547 feet) from the stop end of Runway 07L. The azimuth monitor was on the extended centerline of the runway 30 meters (98 feet) in front of the azimuth antenna enclosure. The elevation subsystem was located 125 meters (402 feet) to the right of the runway centerline and 200 meters (656 feet) from the runway threshold. The elevation monitor was 30 meters (98 feet) in front of and about 6 meters (17 feet) further away from the runway than the elevation antenna enclosure.

The TRSB was flown to the Zaventem Airport aboard a USAF C-141 aircraft, arriving on January 16, 1978. It was off-loaded and trucked to the azimuth and elevation sites in preparation for installation. With the assistance of a crane, both major subsystems were in place on their concrete pads the following day. A unique problem was the removal of existing anchor studs and replacing them with new studs that had to be drilled into the hardened concrete pads. Notwithstanding the above, both systems were in operation by noon the next day.

Figure 3 shows the azimuth subsystem and field monitor situated in the midst of the light lane used for approach to Runway 25R. Figure 4 is the rear view of the azimuth installation facing the stop end of the runway. The Zaventem Airport tower is seen in the distance to the left. Figure 5 is the elevation subsystem as installed near the threshold end of Runway 07L. As viewed from the rear of the elevation site, this figure shows the curved approach area flown in the TRSB demonstrations. The Diegem church tower, to the distant left, at an elevation angle of 1.5 degrees, was a hazard on low approaches.

Figures 6 and 7 show structures on both sides of Runway 07L in the vicinity of the approach/landing zone. These can also be seen in Figure 1 near the landing end of Runway 07L.

The Radio Telemetric Theodolite (RTT) tracker is shown in use near the TRSB elevation site in Figure 8. Its nominal location for 3-degree glide slopes was 30 meters (100 feet) to the rear of the elevation subsystem and 60 meters (200 feet) to the right of Runway 07L. The RTT tracker output is telemetered to the approaching aircraft.

Airborne Instrumentation

The two aircraft used for demonstration of the TRSB are shown in Figure 9. Although of differing demonstration capabilities, the Convair 880 and the Boeing 727 airborne instrumentation for monitoring and recording TRSB flights was similar. The basic airborne equipment consisted of dual angle receivers, course deviation indicators, and precision DME interrogators. Instrumentation required for data acquisition consisted of a data multiplexer, digital data recorder, analog video recorder, strip chart recorder, time code generator, and separate UHF/VHF telemetry receivers. Details of the instrumentation packages on these two aircraft is shown in Figure 10. All data were obtained using omni-directional C-band antenna located on the aircraft as shown in Figure 9.

Operational Demonstrations and Data Acquisition Flights

The TRSB demonstrations were well attended by civil and military aviation officials, news media, and interested visitors from many countries. During the demonstrations in the first week of February, a total of 185 attendees registered for the full schedule of events. Table 1 summarizes those participants registered from 17 countries. These figures do not include some 30 U.S. officials and aviation-oriented personnel who attended the special TRSB demonstration at an earlier date.

Table 2 lists the schedule of demonstration events. TRSB/MLS presentations, ground tours of TRSB installations, demonstration flights, and follow-up critiques, and data discussion and analysis sessions were provided.

Table 3 lists scheduled demonstration flights. The Convair 880, which was equipped to perform curved path and straight-in approaches in addition to autoland, accomplished the majority of those TRSB flights. The flight path and approach to Brussels Airport is illustrated in Figure 11 and Figure 12 as used for both demonstration and data acquisition. The flight geometry of Figure 13 was used for coverage performance checking and data acquisition flights. Table 4 lists the data acquisiton flights. A third of the approaches were autoland. It also lists the C-130 interference tests made. For these tests, two Belgian C-130 Hercules aircraft were positioned at identified points on a parking stand immediately to the right and short of the Runway 07L threshold as shown in Figure 14. This location placed them almost directly in front of the elevation antenna at approximately 300 meters (984 feet) so that the elevation antenna line-of-sight is intercepted at low angles. These aircraft, representing possible multipath obstructions, had been deployed in the same locations during the previous series of Doppler MLS tests at the same runway location.

A limitation encountered in data acquisition at Zaventem was that tracking data could be acquired only during relatively short clearing periods of the generally poor visibility conditions.

Air traffic operations for the TRSB demonstration flights at Brussels were accomplished through close coordination of special flight requirements with the Belgian RVA. An FAA ATCS coordinator was teamed with an RVA controller assigned to the TRSB project. This team participated in all joint FAA/RVA demonstration flight briefings with the air crews and carried out the IFR control room operations involving demonstration flights and data acquisition flights.

Performance Assessment

Aircraft tracking for TRSB demonstration and data flights at Brussels was provided, as discussed previously, by a manually operated RTT. During the flight test period, due to limited visibility, the RTT was used only to track elevation approaches of the CV-880 and B-727. An automatic tracker which uses a sensitive vidicom tube, was not available as it was being used during this time period to track TRSB flights at Charleroi, Belgium.

The RTT was adjusted on the ground to have the same sensitivity as the TRSB receiver elevation analog output in the aircraft. While manually tracking the aircraft with the theodolite, the RTT angle data was simultaneously transmitted to the aircraft where it was received, decoded, and combined with the TRSB angle signal to produce a differential error plot. In addition, the receiver output and the tracker output were also recorded.

These traces were plotted on an airborne light galvanometer type strip chart recorder. It is to be noted that, during the demonstration activity at Brussels, visibility conditions rarely exceeded 2 to 3 miles. Although this visibility did not permit azimuth tracking, the received TRSB azimuth signal was recorded. In addition to the light sensitive strip chart recorder, a digital recorder was available in both demonstration aircraft. Since only analog data was available from the RTT, the digital information recorded was angle data from the TRSB receivers and time code data. Examples of NAFEC processed digital TRSB data are presented in Appendix C.

Analog strip chart recordings from flights conducted on the FAA CV-880 and B-727 aircraft during the demonstration period are presented in Figures 15 through 20. Tracker and alignment bias errors have been taken out of these analog data plots. From these figures, it is evident that the maximum tracking range was approximately 6 nautical miles, while more often good tracking could only be provided for a distance of between 2 and 3 nautical miles. The regions of valid tracking show the Basic Wide TRSB elevation subsystem to be within ICAO (AWOP) "full capability system" requirements.

As expected in the special tests with two C-130 Hercules aircraft in the low angle scan of the elevation beam, interference was noted when line-of-sight blocking occurred from the tail assembly of the C-130. The interference occurred at an approach elevation angle of about 2.0 degrees and is strictly a function of geometry and frequency of operation (C-band), not the system design or signal format. In accordance with a bilateral agreement, the UK/CAA also collected data on the TRSB at this site (and at Kristiansand, Norway). During the CAA flights, visibility conditions were improved enough to track from the azimuth site. Therefore the only azimuth error plots available are those taken by the UK/CAA. The UK/CAA designed the necessary interface to install TRSB components in their HS-748 twin turbo prop aircraft. (This was the same aircraft and TRSB installation the UK/CAA used in flying against the TRSB Basic Narrow System at Kristiansand, Norway. A separate report covers the Kristiansand demonstration of TRSB.)

Sample data plots obtained by the UK/CAA are shown in Appendix D. Three separate plots, tracker, angle receiver output, and error plots are provided by the U.K. This data contains "spikes" not normally seen in TRSB data and are believed to be caused by the recorder interface equipment aboard the U.K. aircraft. See Appendix C for sample plots of TRSB digital data recorded in FAA's CV-880 aircraft. These plots, which show only TRSB receiver output, do not contain any "extraneous spikes." Therefore, for data presentation, an additional plot has been added for each U.K. data run (set of three plots) which has the "spikes" removed. Also noticeable in the CAA collected data on the TRSB elevation system is a negative trend in the error data. This is not seen in the FAA collected data and is believed due to tracker positioning on a convenient concrete pad.

As in the FAA elevation data plots, the CAA error data plots show that the performance of the TRSB Basic Wide configuration is within the ICAO (AWOP) error limits for the "full capability system."

SUMMARY OF RESULTS

Operational demonstrations provided to large numbers of international aviation representatives, officials, and aviation oriented visitors were well received and acknowledged.

The Basic Wide TRSB equipment provided high accuracy aircraft approach and landing guidance suitable for complex approach paths and automatic landings. Although designed for use at high density, heavily trafficked airports, it is relatively small and compact and was shown to be uncomplicated of installation and alignment. This was seen to be the case at Zaventem Airport, Brussels, Belgium, even under the adverse weather conditions of the winter season.

Although the same adverse weather conditions limited data acquisition, the samples with good tracking available in both the U.S. and U.K. data show that the TRSB, on both manual and autoland flights, was consistently able to guide and land aircraft along straight-in and curving approaches at a large European airport with negligible influence from multipath reflections and performs within the "full capability system" requirements of ICAO.

TABLE 1
SUMMARY STATISTICS

TRSB operational demonstration at Brussels, Belgium, February 1 through February 3, 1978.

Registered Visitors

February 1	(Press)	14
	(Other)	51
February 2	(Press)	2
	(Other)	54
February 3	(TV)	2
	(Other)	62
	Total	185

Flight Demonstrations	Observers B-727	Observers CV-880
February 1	27	21
February 2	27	46
February 3	11	53
Total	65	120
Grand Total	185	

Countries Represented

Belgium	86	Spain	3
United States	21	Austria	2
Italy	14	Ireland	2
France	14	Greece	2
United Kingdom	13	Luxembourg	2
Germany	9	Netherlands	2
Switzerland	4	Norway	2
Finland	4	Portugal	2
Denmark	3		

Total 185

TABLE 2

SCHEDULE OF EVENTS

UNITED STATES OF AMERICA
TRSB DEMONSTRATION PROGRAM
BRUSSELS, BELGIUM

February 1, 2, and 3, 1978

TRSB Presentation		0900	1030
		1100	1230
Introduction			
TRSB Film			
TRSB System Hardware			
ICAO/AWOP MLS Program			
Questions and Answers			
Visit to TRSB Ground Facilities:			
	Zaventem Airport	1045	1145
		1200	1300
	Gosselies Airport	1430	1530
TRSB Flight Demonstrations:			
	CV-880	0930	1030
		1045	1145
		1200	1300
	B-727	0930	1030
		1045	1145
		1300	1400

Note: The program schedule was flexible and was adjusted to accomodate visitors.

TABLE 3

TRSB OPERATIONAL DEMONSTRATION FLIGHTS AT ZAVENTEM AIRPORT, BRUSSELS, BELGIUM

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial Altitude	
FAA Boeing 727 Testbed Aircraft							
2/1/78	1	Approach	0°	3°	10 nmi	3,100 feet	
	2	Approach	0°	3°	10 nmi	3,100 feet	
2/2/78	1	Approach	0°	3°	10 nmi	3,100 feet	
	2	Approach	0°	3°	10 nmi	3,100 feet	
	3	Approach	0°	3°	10 nmi	3,100 feet	
	4	Approach	0°	3°	10 nmi	3,100 feet	
2/3/78	1	Approach	0°	3°	10 nmi	3,100 feet	
	2	Approach	0°	3°	10 nmi	3,100 feet	
FAA Convair 880 Testbed Aircraft							
2/1/78 (a)	2	Approach	CP	3°	11 nmi	3,800 feet	
	3	Approach	CP	3°	11 nmi	3,800 feet	AL
	5	Approach	CP	3°	11 nmi	3,800 feet	AL
	6	Approach	CP	3°	11 nmi	3,800 feet	
	7	Approach	CP	3°	11 nmi	3,800 feet	
	8	Approach	CP	3°	11 nmi	3,800 feet	AL
2/2/78 (b)	2	Approach	CP	3°	11 nmi	ANR	
	3	Approach	CP	3°	11 nmi	ANR	AL
	4	Approach	0°	3°	10 nmi	ANR	
	5	Approach	0°	3°	10 nmi	ANR	
	6	Approach	CP	3°	11 nmi	ANR	
	7	Approach	CP	3°	11 nmi	ANR	AL
	8	Approach	CP	3°	11 nmi	ANR	

TABLE 3 (continued)

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial Altitude
2/3/78	1	Approach	0°	3°	11 nmi	ANR
	2	Approach	CP	3°	11 nmi	ANR
	3	Approach	CP	3°	11 nmi	ANR
	4	Approach	CP	3°	11 nmi	ANR AL
	5	Approach	CP	3°	11 nmi	ANR
	6	Approach	CP	3°	11 nmi	ANR
	7	Approach	CP	3°	11 nmi	ANR

Legend: CP - Curved Path
ANR - Altitude Not Recorded
(a) Runs 1 and 4 were made at Gosselies Airport, Charleroi, Belgium
(b) Run 1 was made at Gosselies Airport, Charleroi, Belgium
AL - Autoland

TABLE 4

TRSB DATA ACQUISITION FLIGHTS AT ZAVENTEM AIRPORT, BRUSSELS, BELGIUM

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial/Constant Altitude
1/20/78	1	Radial	39° L	3°	20 nmi	I - 6,000 feet
	2	Approach	0°	3°	10 nmi	I - 6,000 feet
	3	Radial	39° R	3°	10 nmi	I - 6,000 feet
	4	Orbit ±60° Clockwise	--	2°	20 nmi	I - 6,000 feet
	5	Approach	0°	2°	10 nmi	I - 2,000 feet
1/23/78	1	Approach	0°	3°	10 nmi	I - 2,000 feet
	2	Approach	0°	3°	10 nmi	I - 2,000 feet
	3	Approach	0°	2°	12 nmi	I - 2,000 feet AL
	4	Approach	0°	4°	15 nmi	I - 2,800 feet
	5	Orbit ±60° Clockwise	--	3°	6 nmi	C - 1,900 feet
	6	Orbit ±60° CounterCW	--	3°	6 nmi	C - 1,900 feet
	7	Orbit ±60° Clockwise	--	2°	20 nmi	C - 3,000 feet
	8	Radial	39° L	2°	10 nmi	C - 3,000 feet
1/26/78	1	Radial	39° R	3°	10 nmi	C - 3,000 feet
	2	Radial	39° L	3°	10 nmi	C - 3,000 feet
	3	Radial	0°	3°	15 nmi	C - 3,000 feet
	4	Approach	0°	2°	12 nmi	I - 1,900 feet
	5	Approach	0°	3°	12 nmi	I - 1,500 feet
	6	Approach	0°	4°	10 nmi	I - 2,100 feet AL
1/30/78	1	Approach	0°	3°	8 nmi	I - 2,000 feet
	2	Approach	0°	3°	10 nmi	I - 2,000 feet AL
	3	Approach	0°	3°	10 nmi	I - 2,000 feet
	4	Approach	0°	3°	10 nmi	I - 2,000 feet

TABLE 4 (continued)

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial/Constant Altitude
1/31/78	1	Approach	CP	3°	11 nmi	I - 3,000 feet AL
	2	Approach	CP	3°	11 nmi	I - 2,700 feet AL
	3	Approach	CP	3°	11 nmi	I - 3,000 feet AL
	2*	Approach	0°	2°	7 nmi	ANR
	4*	Approach	0°	3°	7 nmi	ANR
	6*	Approach	0°	4°	7 nmi	ANR
	7*	Approach	0°	4°	7 nmi	ANR

Legend: * - Interference tests with C-130 Transport Aircraft (Runs 1, 3, and 5 not recorded).
I - Initial
C - Constant
CP - Curved Path
ANR - Altitude Not Recorded
AL - Autoland

TABLE 5

ICAO (AWOP) FULL AND REDUCED CAPABILITY CONFIGURATION ERROR LIMITS

AWOP System Configuration	Distance to Error Window (Feet)	Permitted Error (2 Sigma) Feet	Degrees
Reduced Capability (Elevation)	4,000	±10	0.14 ±0.10 noise ±0.10 bias
Reduced Capability (Azimuth)	10,000	±40	±0.23 ±0.16 noise ±0.16 bias
Full Capability (Elevation)	1,145	±2.0	±0.10 ±0.07 noise ±0.07 bias
Full Capability (Azimuth)	15,000	±20	±0.076 ±0.054 noise ±0.054 bias

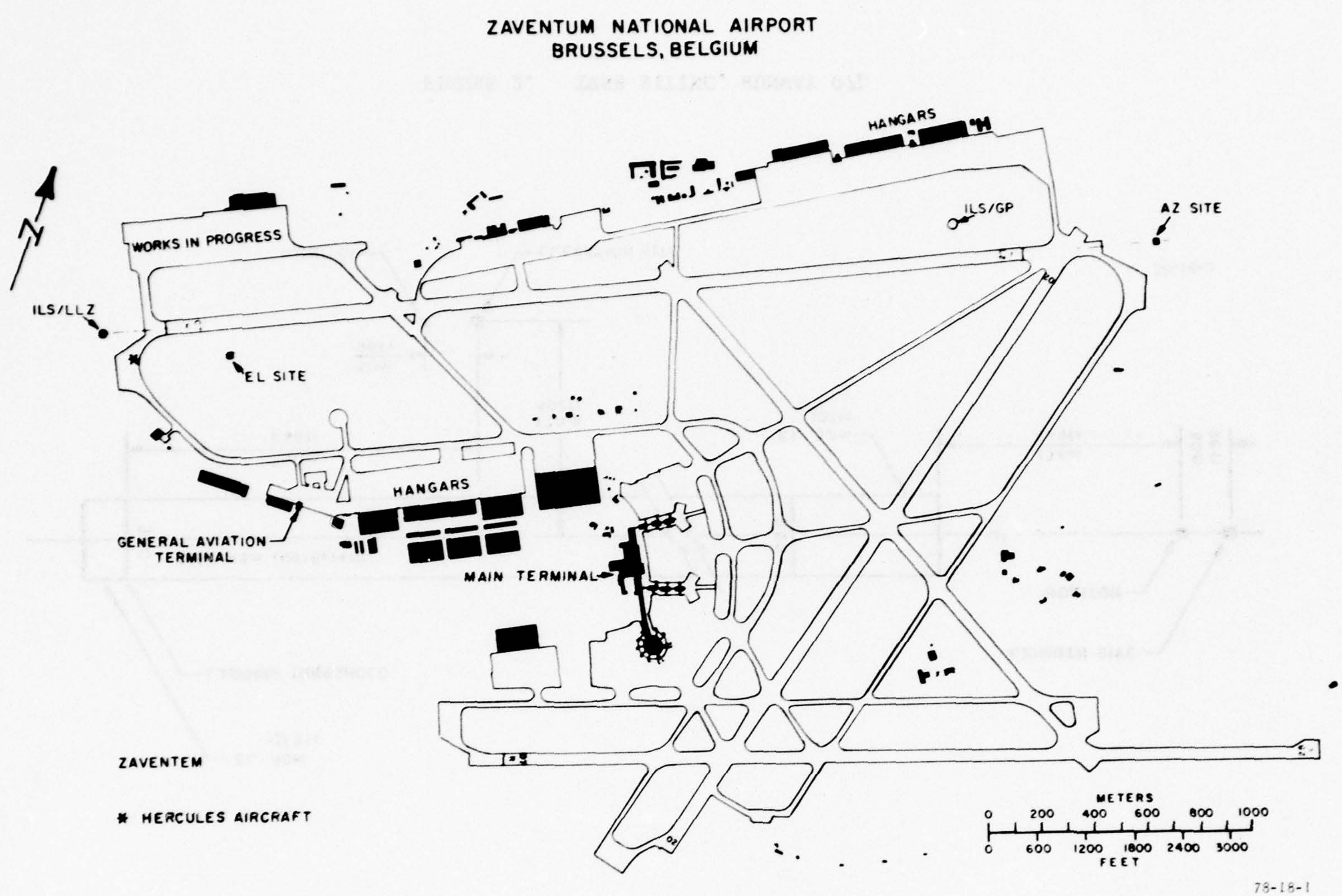

FIGURE 1. GENERAL PLAN OF ZAVENTEM AIRPORT, BRUSSELS, BELGIUM

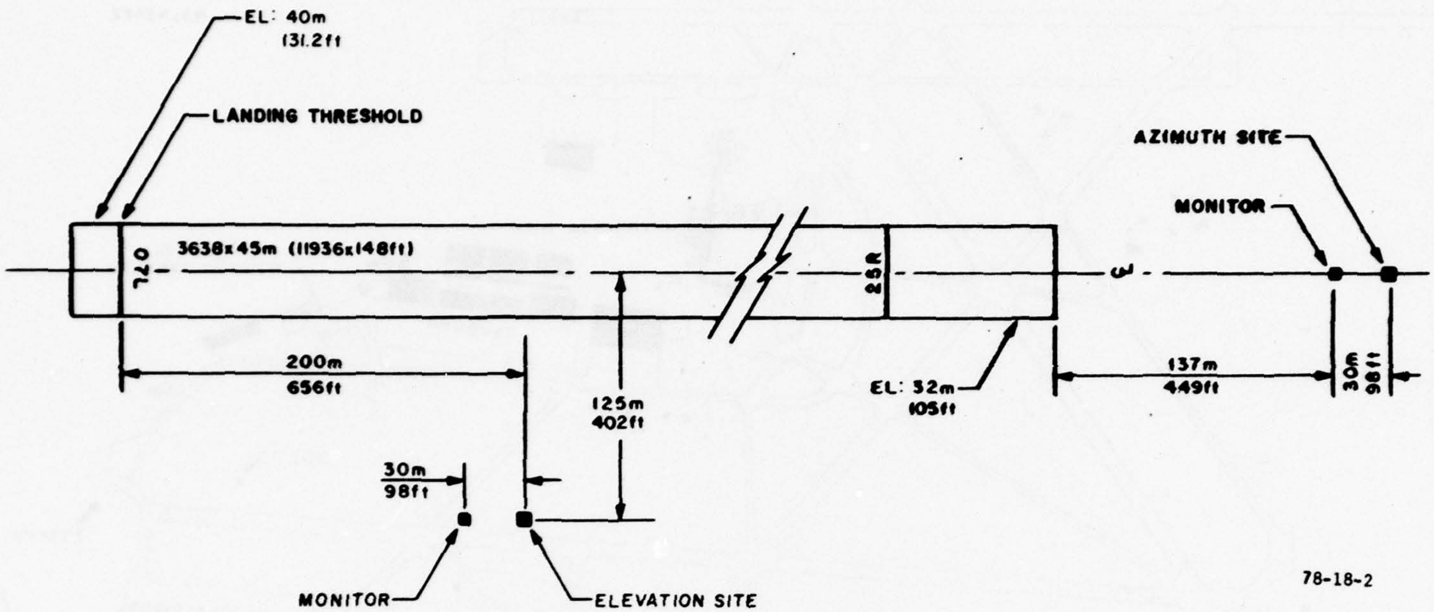

FIGURE 2. TRSB SITING, RUNWAY 07L

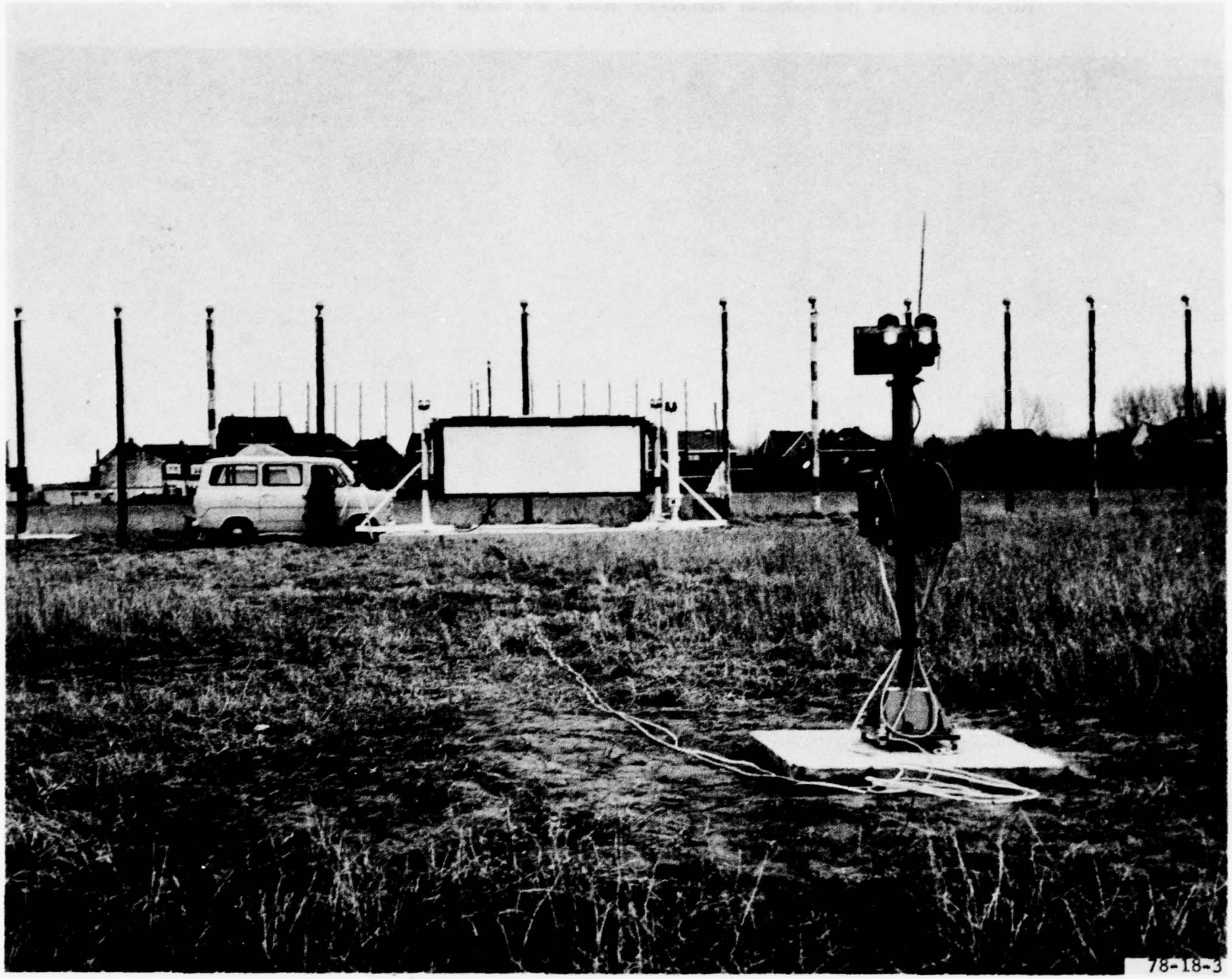

FIGURE 3. TRSB AZIMUTH SUBSYSTEM AT STOP END OF RUNWAY 07L

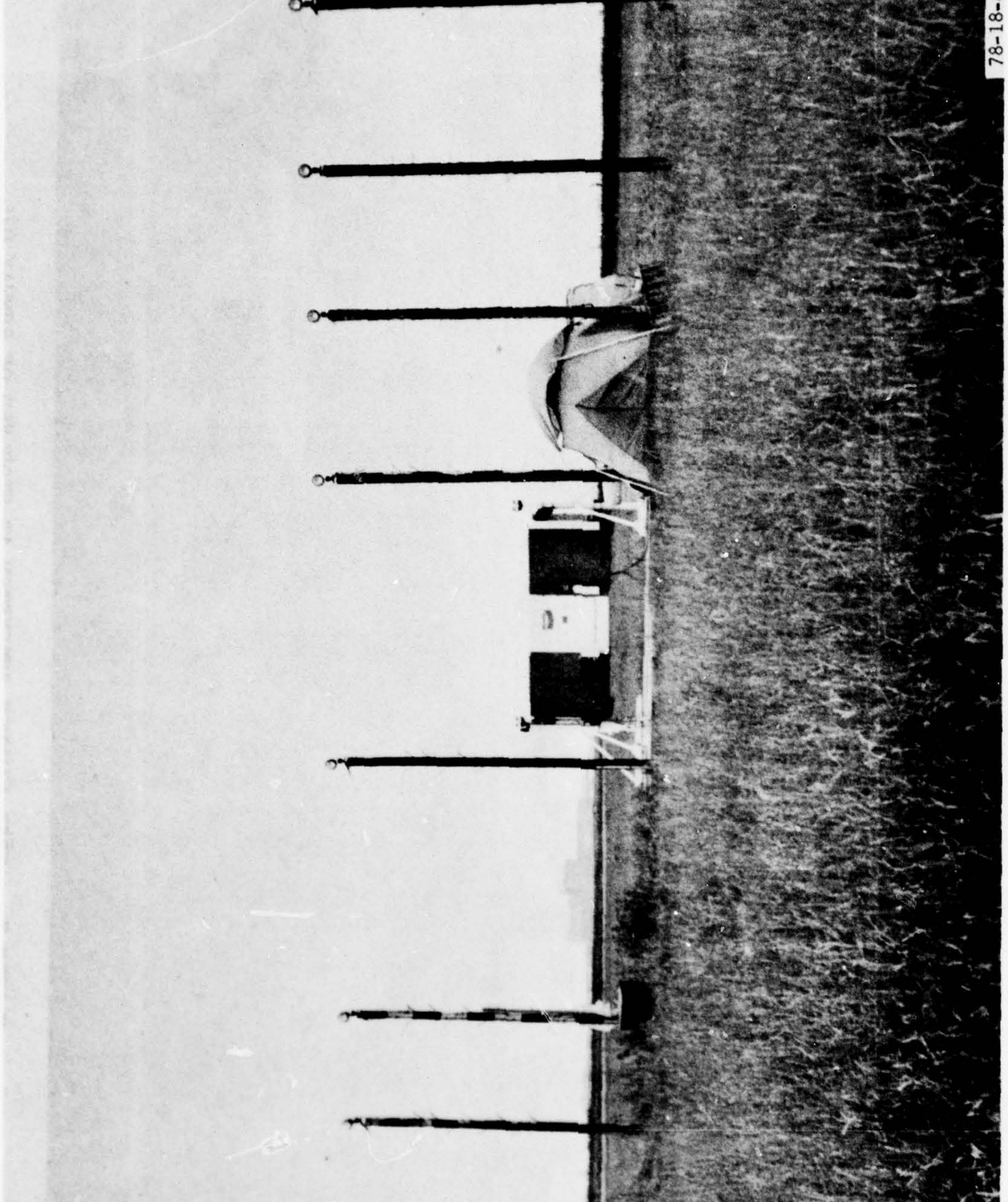

FIGURE 4. REAR VIEW OF TRSB AZIMUTH SUBSYSTEM INSTALLATION

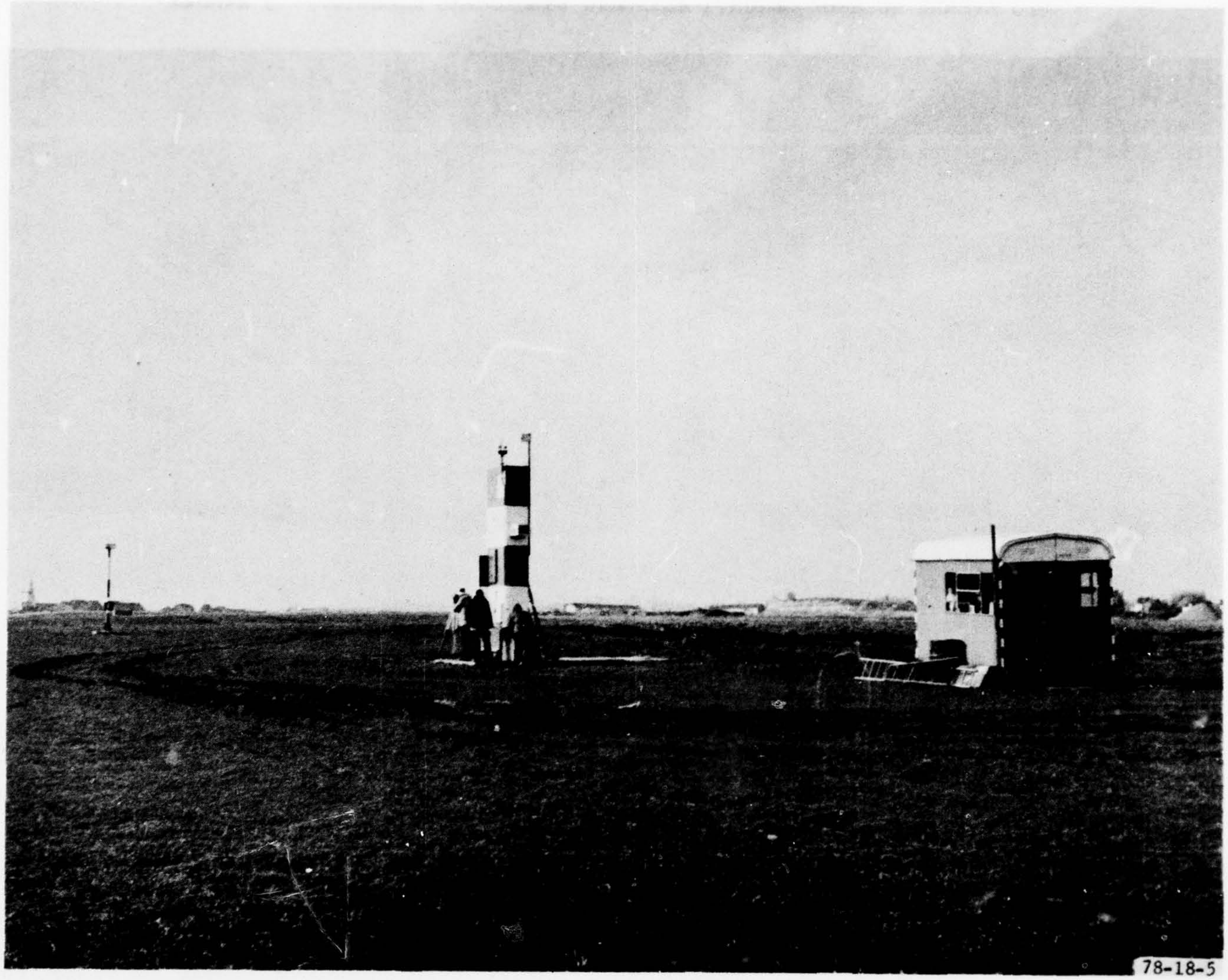

FIGURE 5. TRSB ELEVATION SUBSYSTEM NEAR THRESHOLD END OF RUNWAY 07L

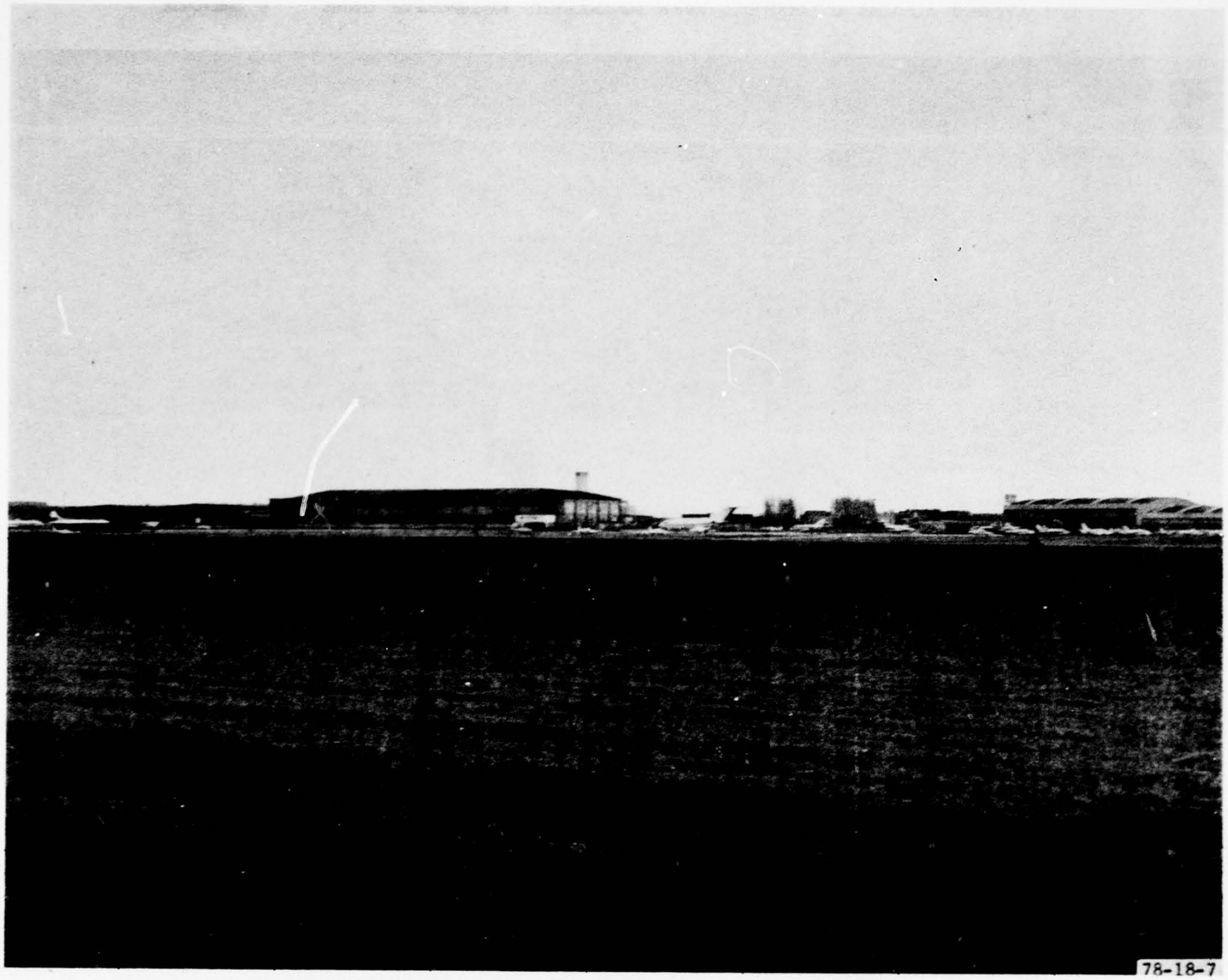

FIGURE 6. AIRPORT STRUCTURES OPPOSITE LANDING ZONE OF RUNWAY 07L

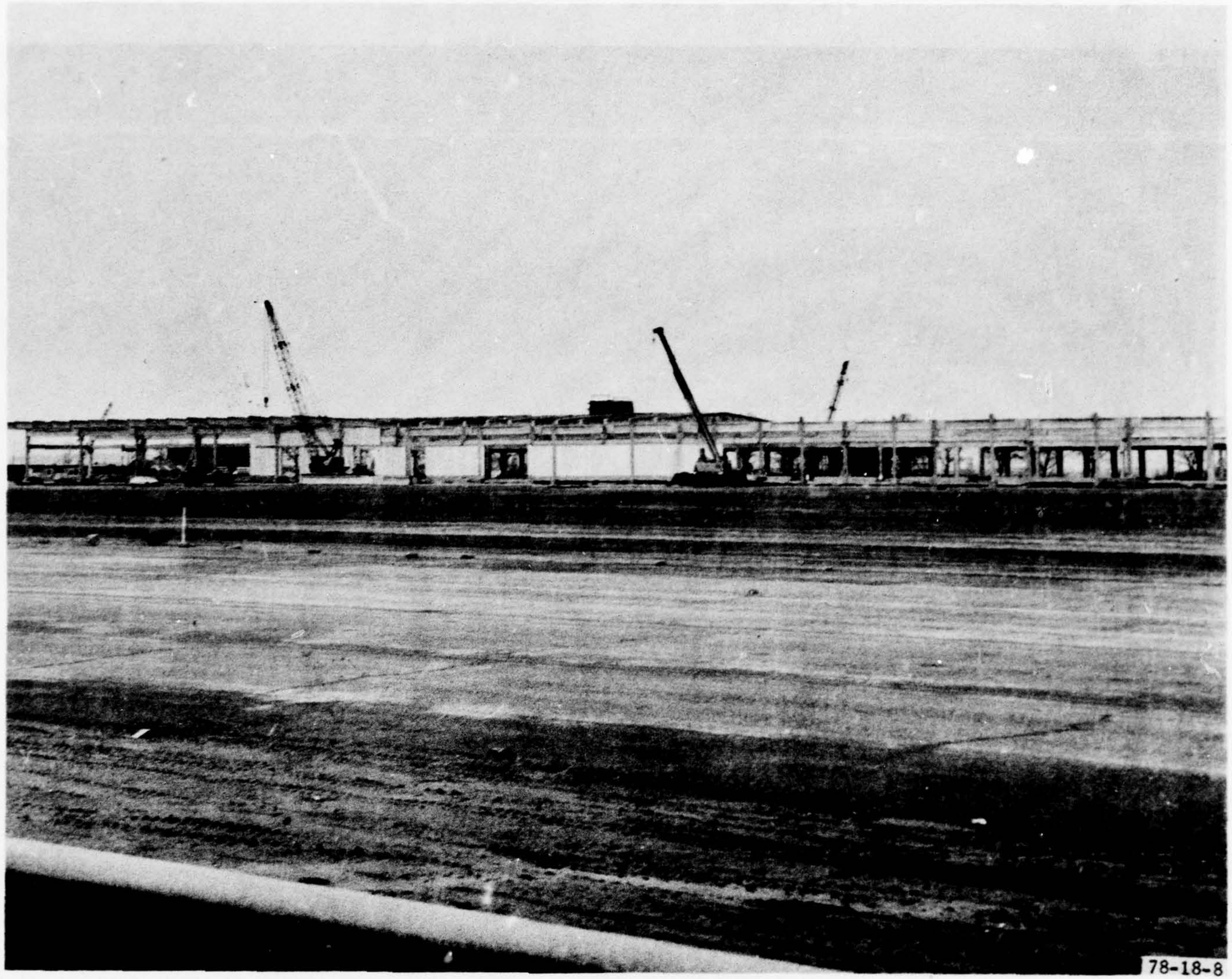

FIGURE 7.   CONSTRUCTION IN PROGRESS OPPOSITE LANDING ZONE OF RUNWAY 07L

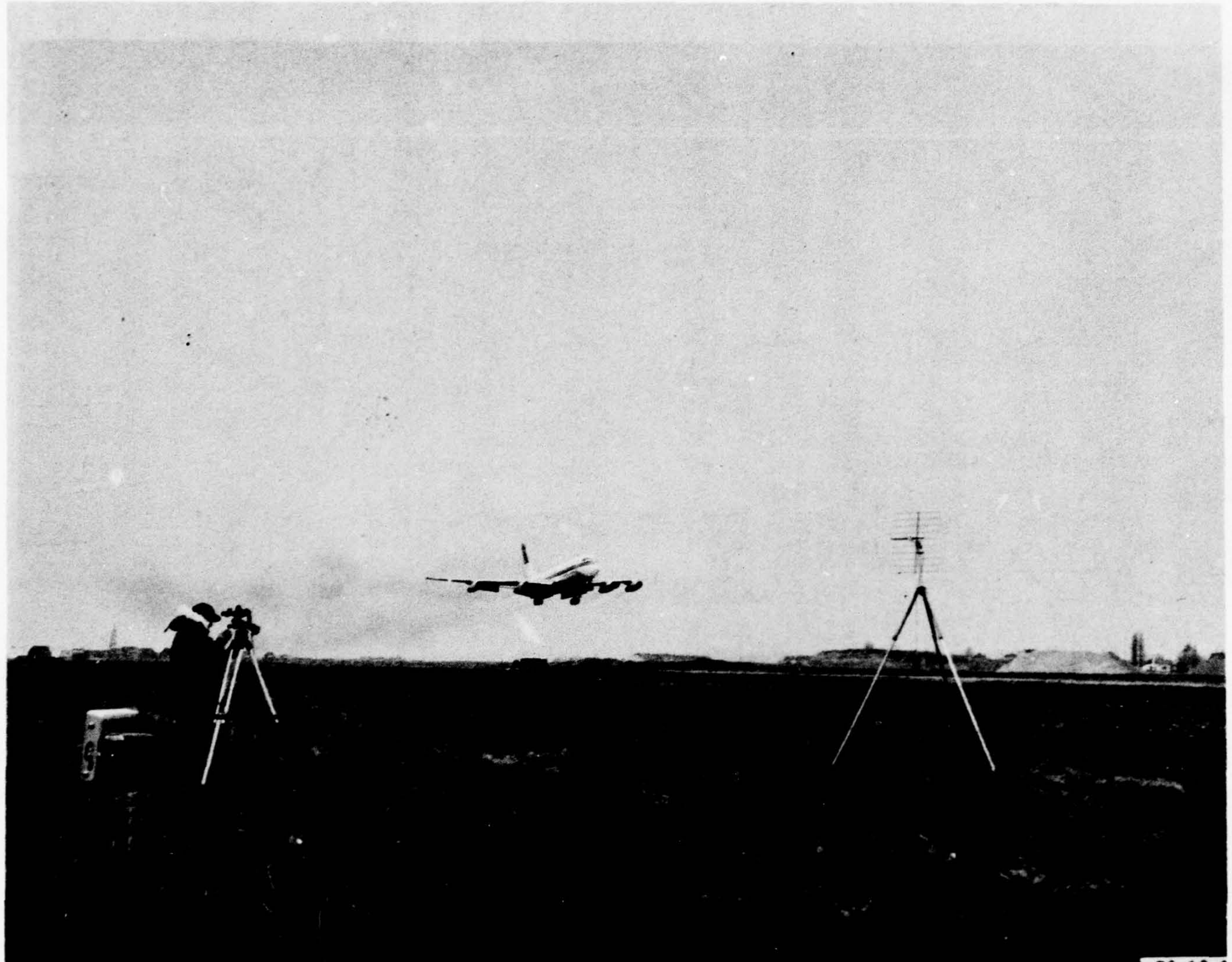

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FIGURE 8. RADIO TELEMETRIC THEODOLITE (RTT) TRACKER NEAR TRSB ELEVATION SITE

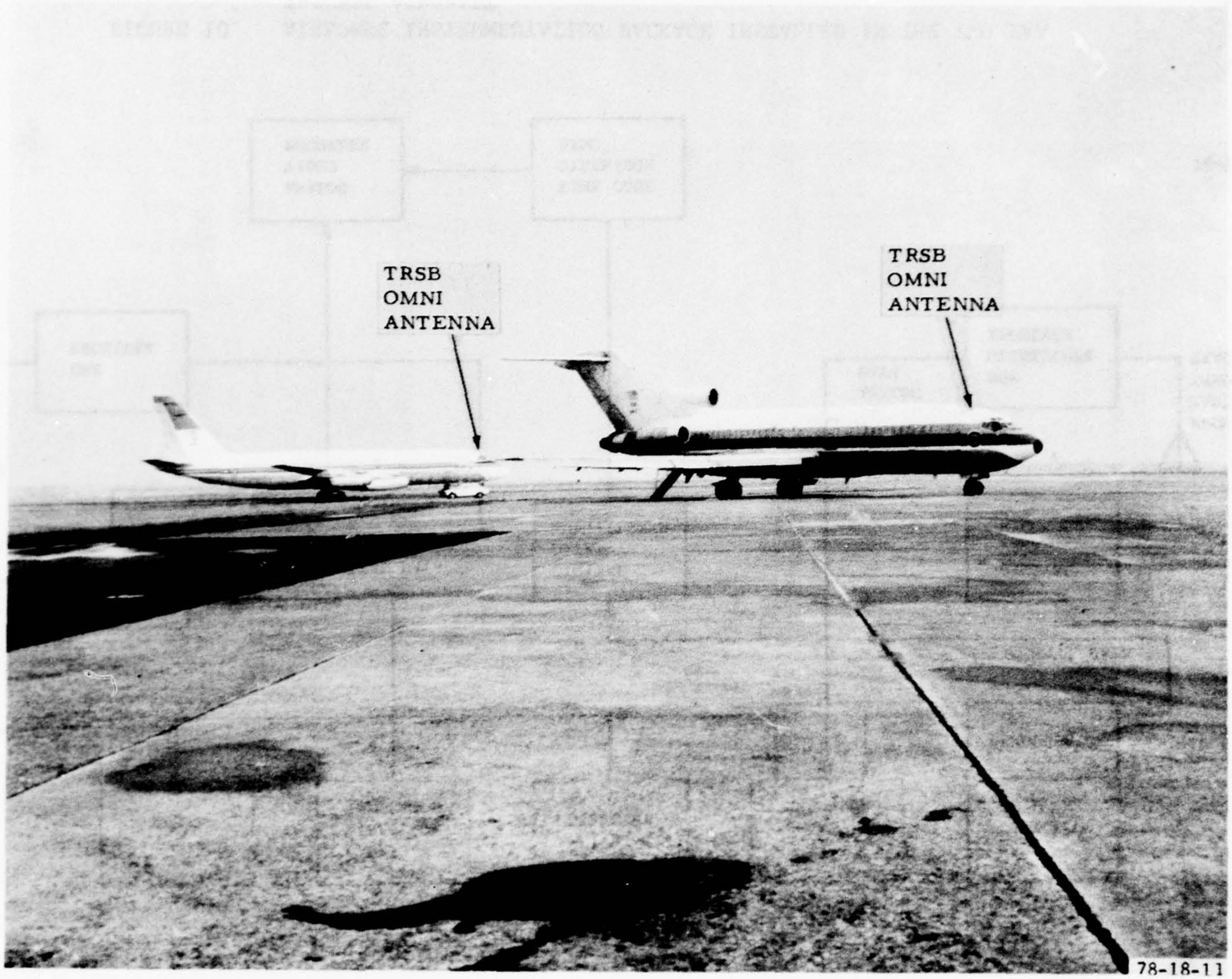

FIGURE 9. CONVAIR 880 AND BOEING 727 TESTBED AIRCRAFT, ZAVENTEM AIRPORT

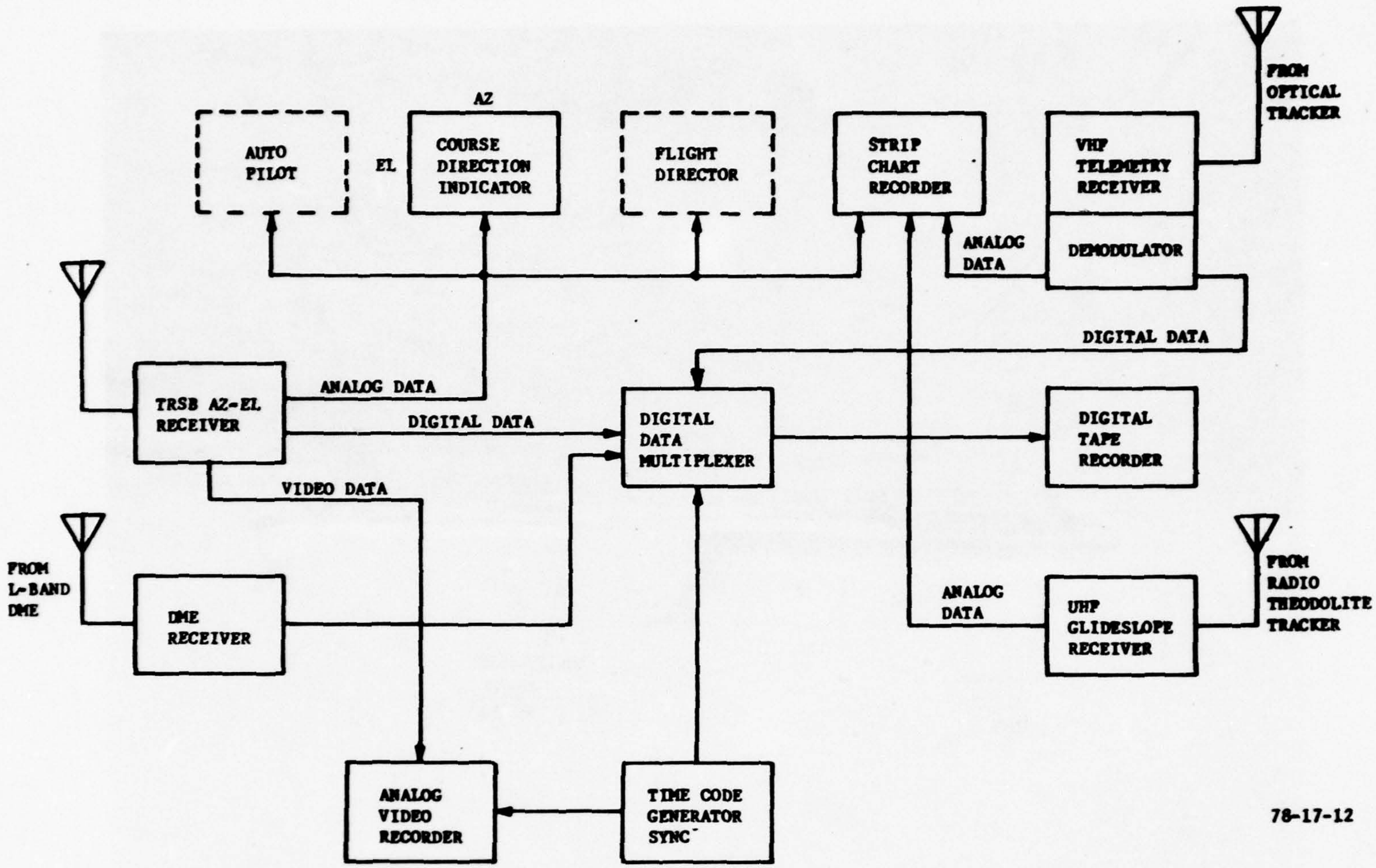

FIGURE 10. AIRBORNE INSTRUMENTATION PACKAGE INSTALLED IN THE TWO FAA TESTBED AIRCRAFT

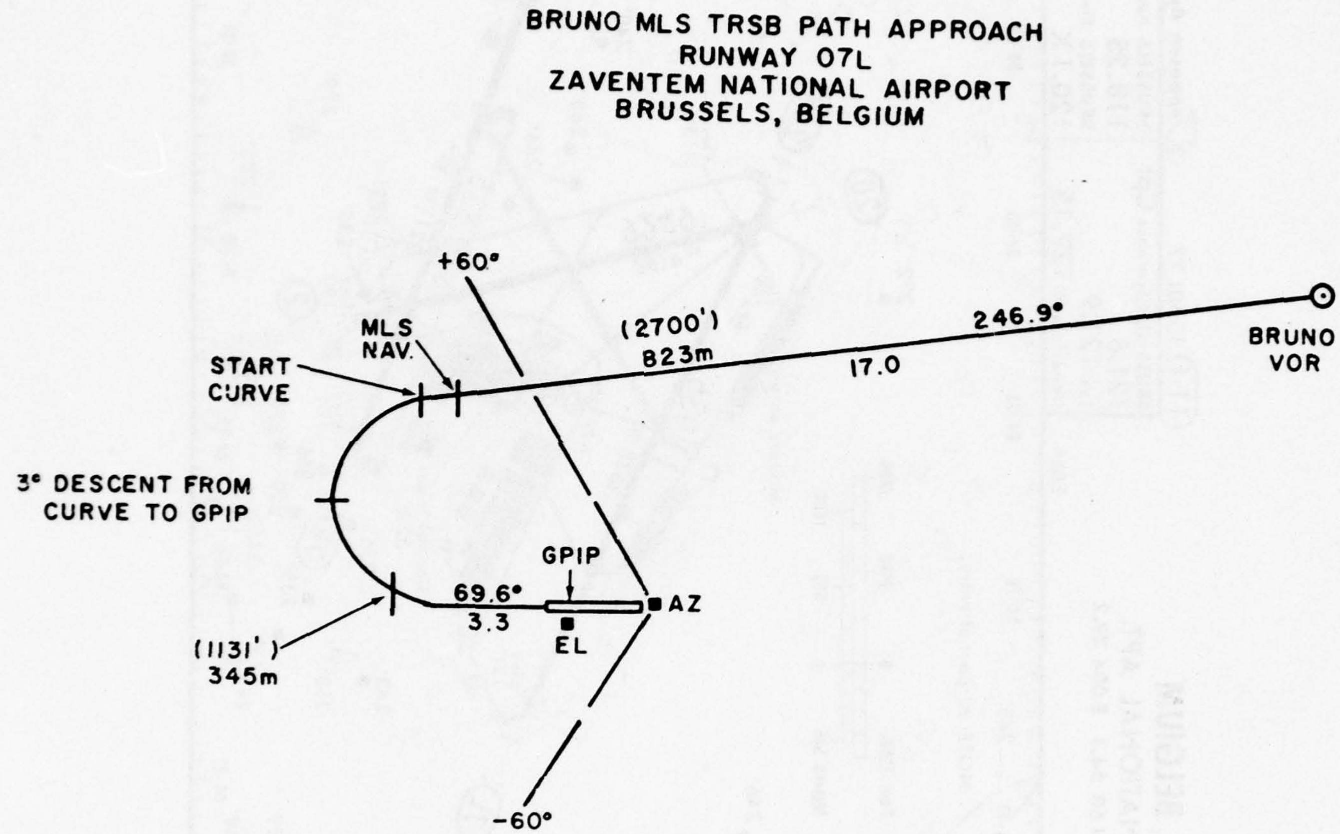

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FIGURE 11. CURVED PATH APPROACH (BRUNO) TO RUNWAY 07L

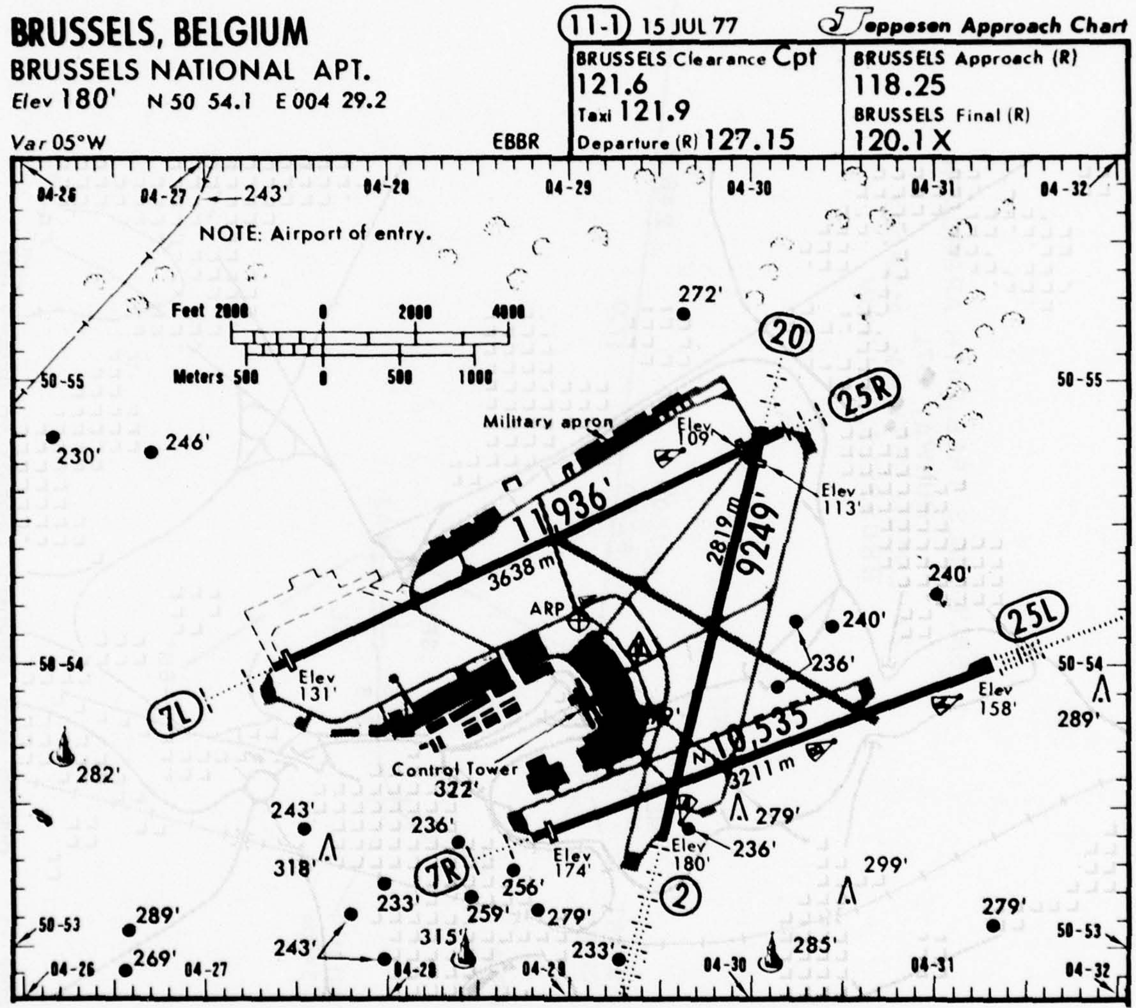


FIGURE 12. APPROACH CHART FOR BRUSSELS NATIONAL AIRPORT

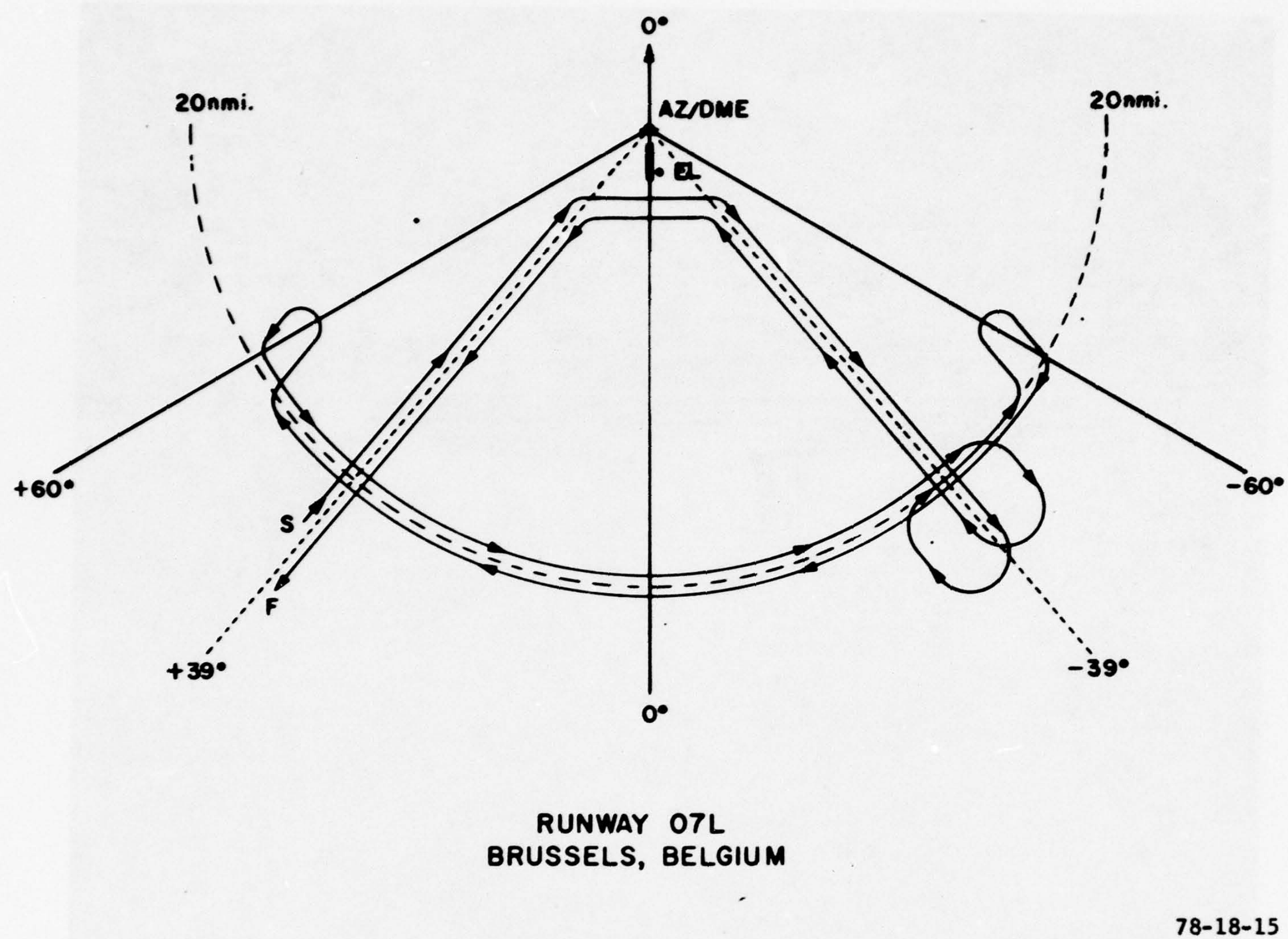


FIGURE 13. TRSB COVERAGE PATTERNS

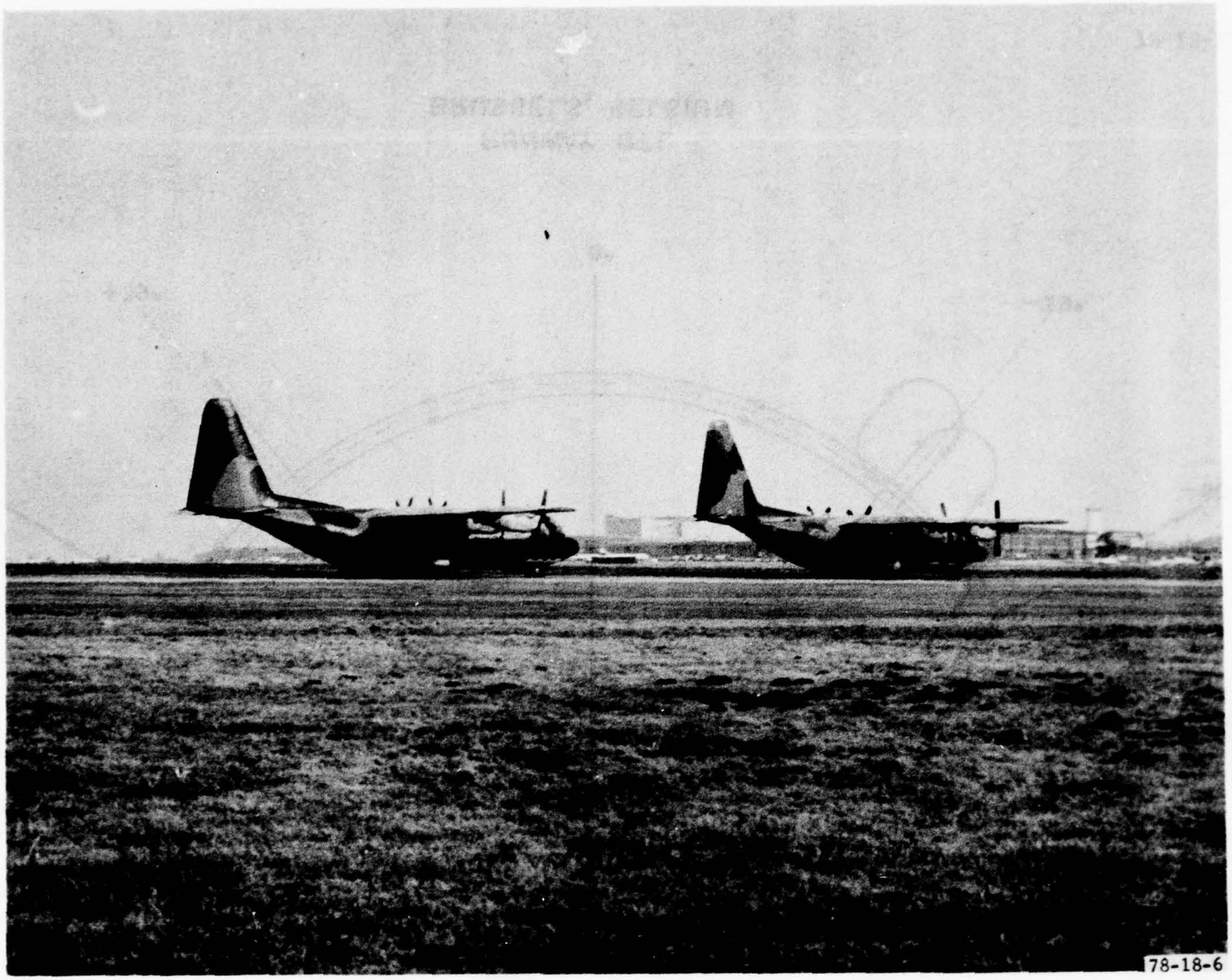


FIGURE 14. HERCULES AIRCRAFT NEAR THRESHOLD END OF RUNWAY IN LINE WITH TRSB ELEVATION ANTENNA

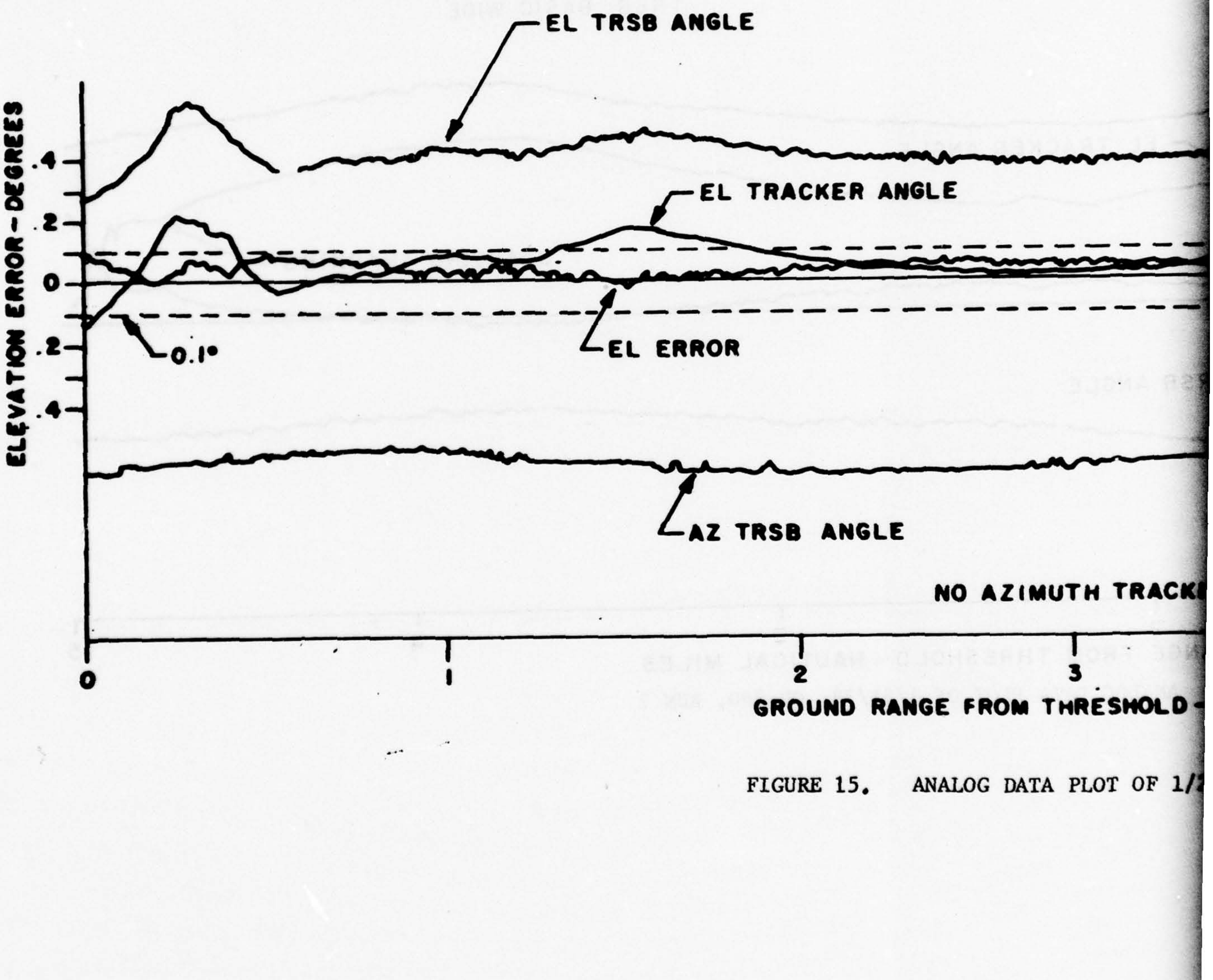
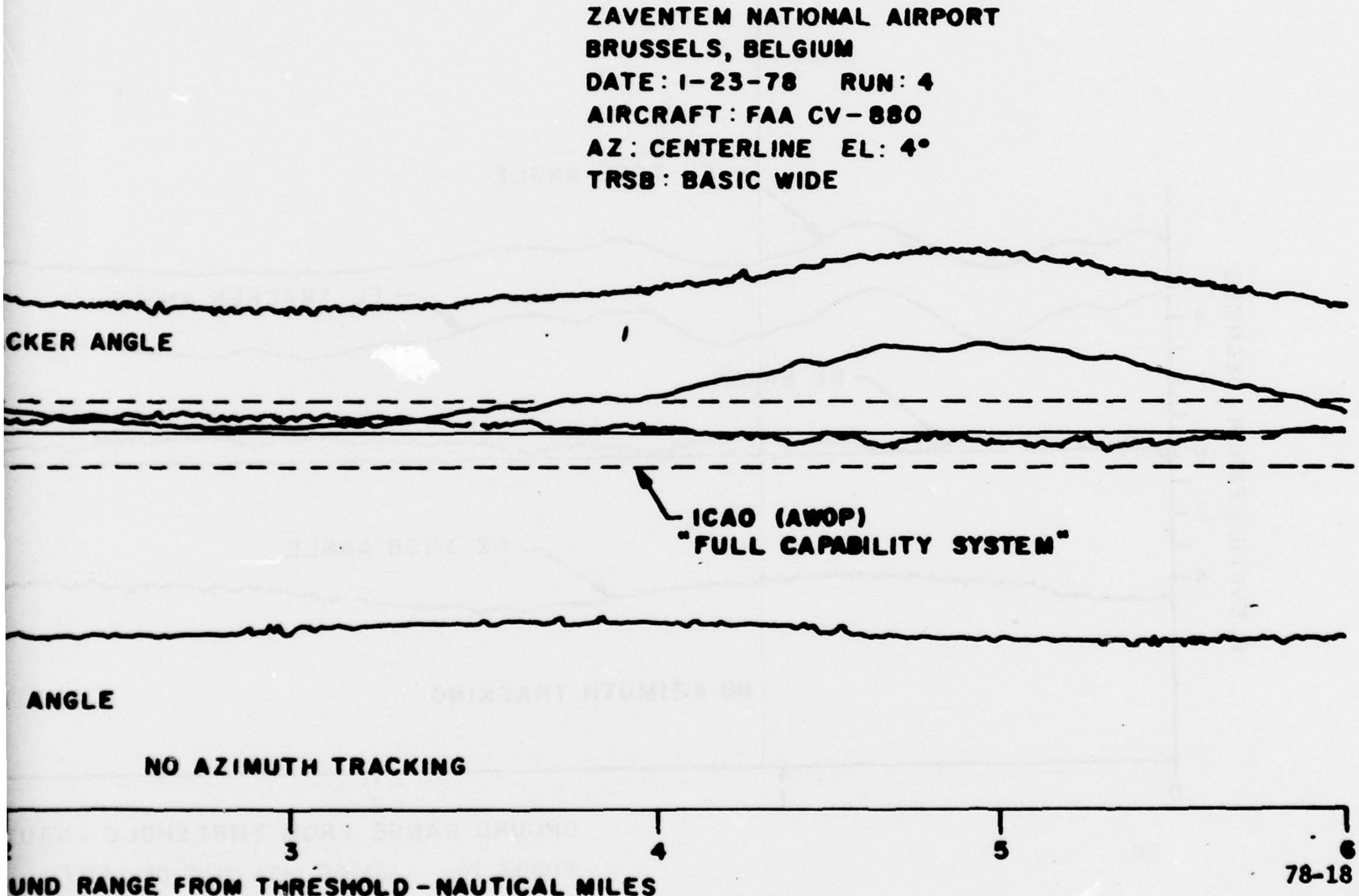


FIGURE 15. ANALOG DATA PLOT OF 1/



E 15. ANALOG DATA PLOT OF 1/23/78, CV-880, RUN 4

NOTE: C130 Hercules Aircraft in Place for Elevation Shadowing/Multipath Test

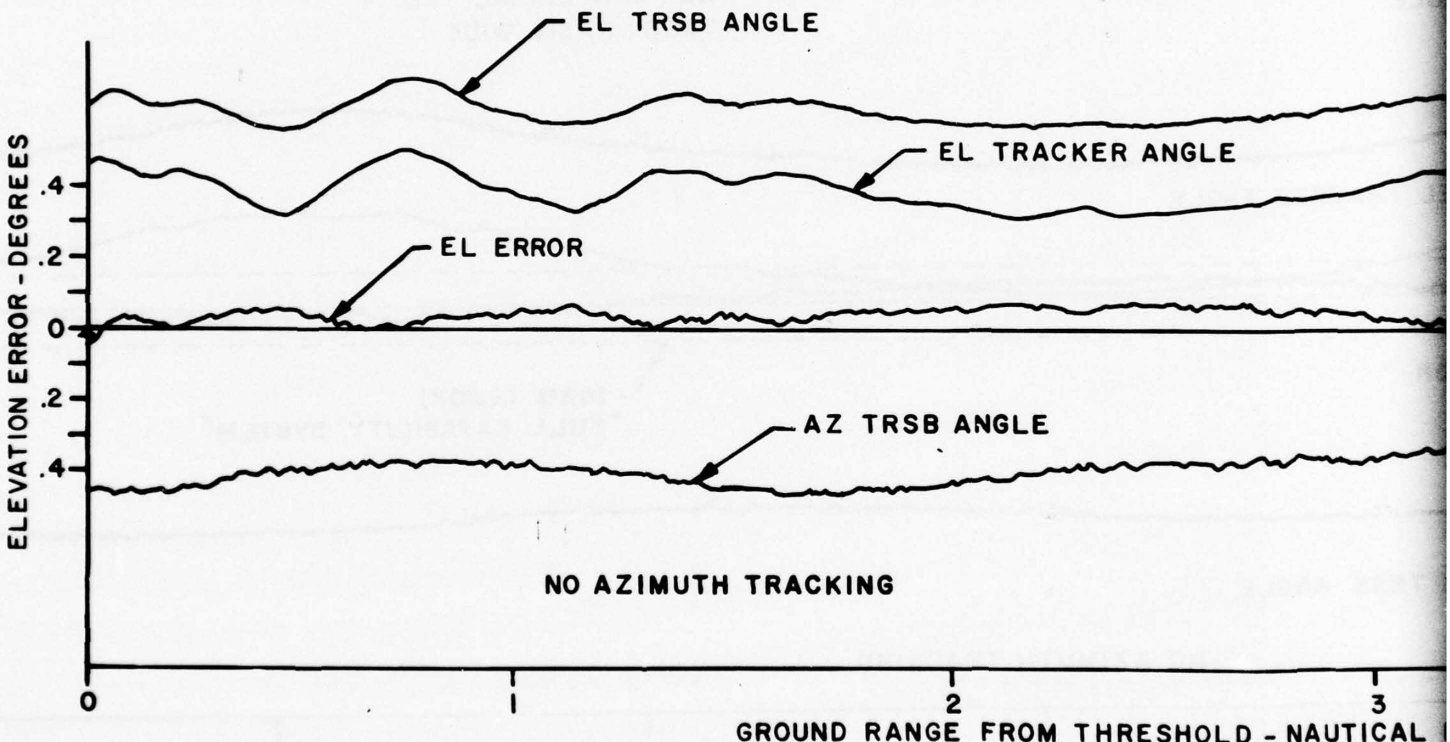
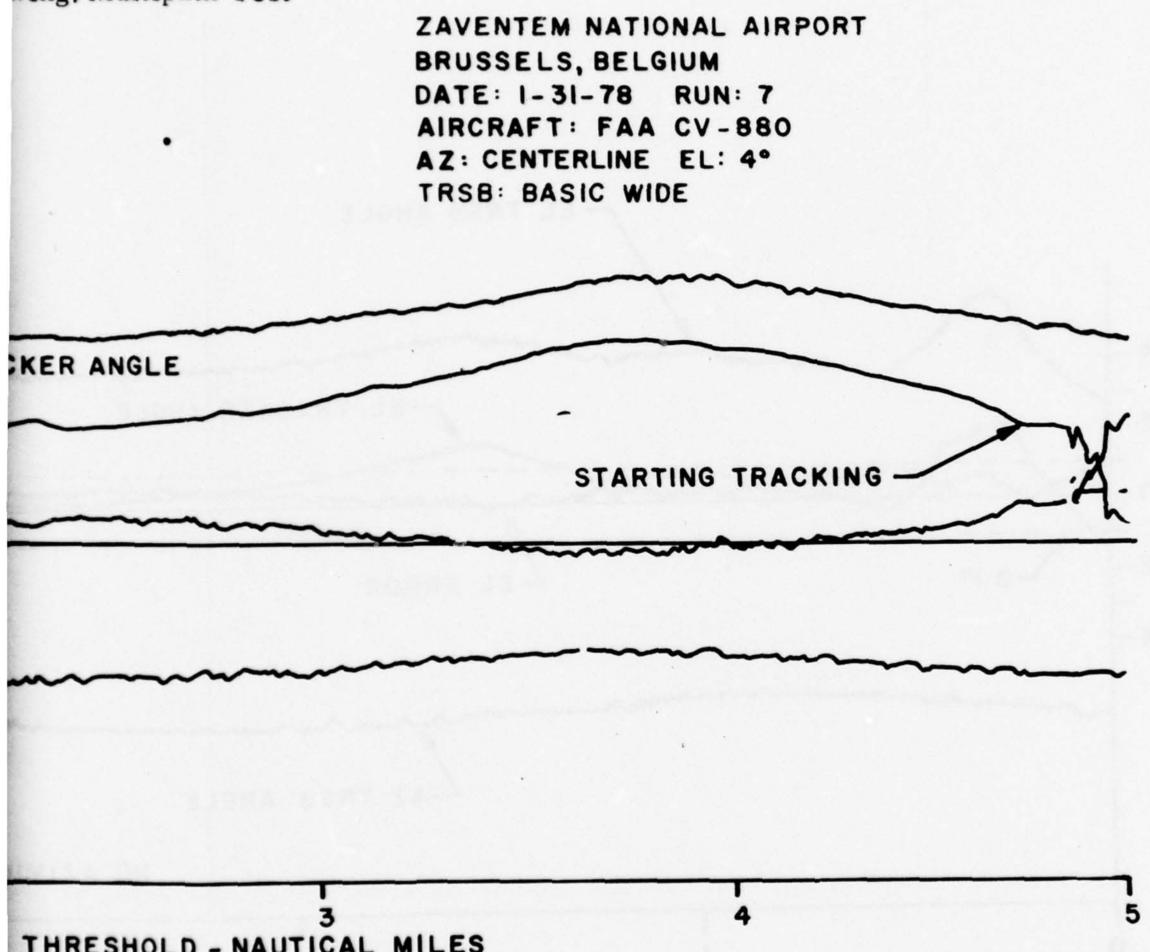


FIGURE 16. ANALOG DATA PLOT OF 1/31/78, CV-880,

wing/Multipath Test



TA PLOT OF 1/31/78, CV-880, RUN 7

2

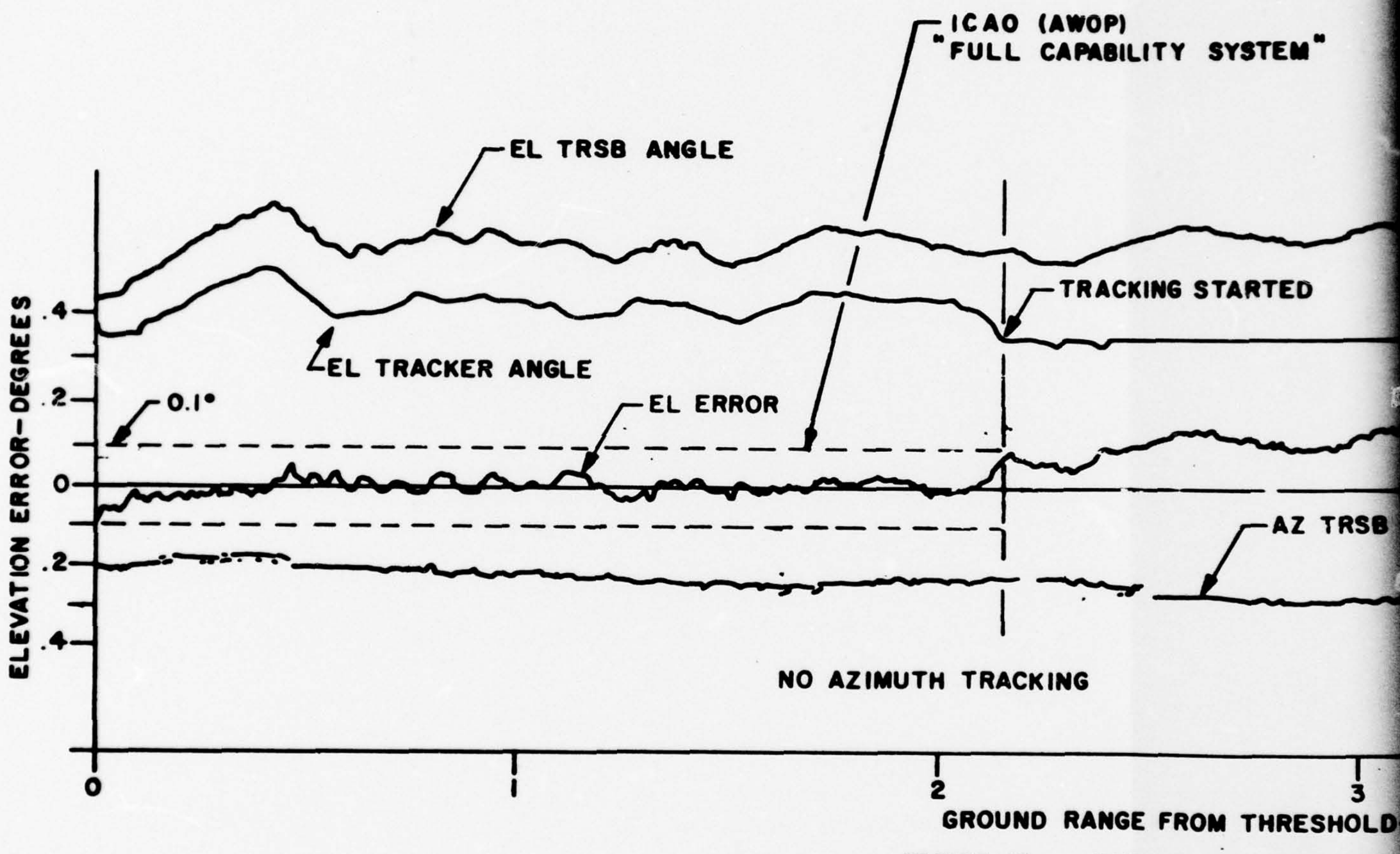
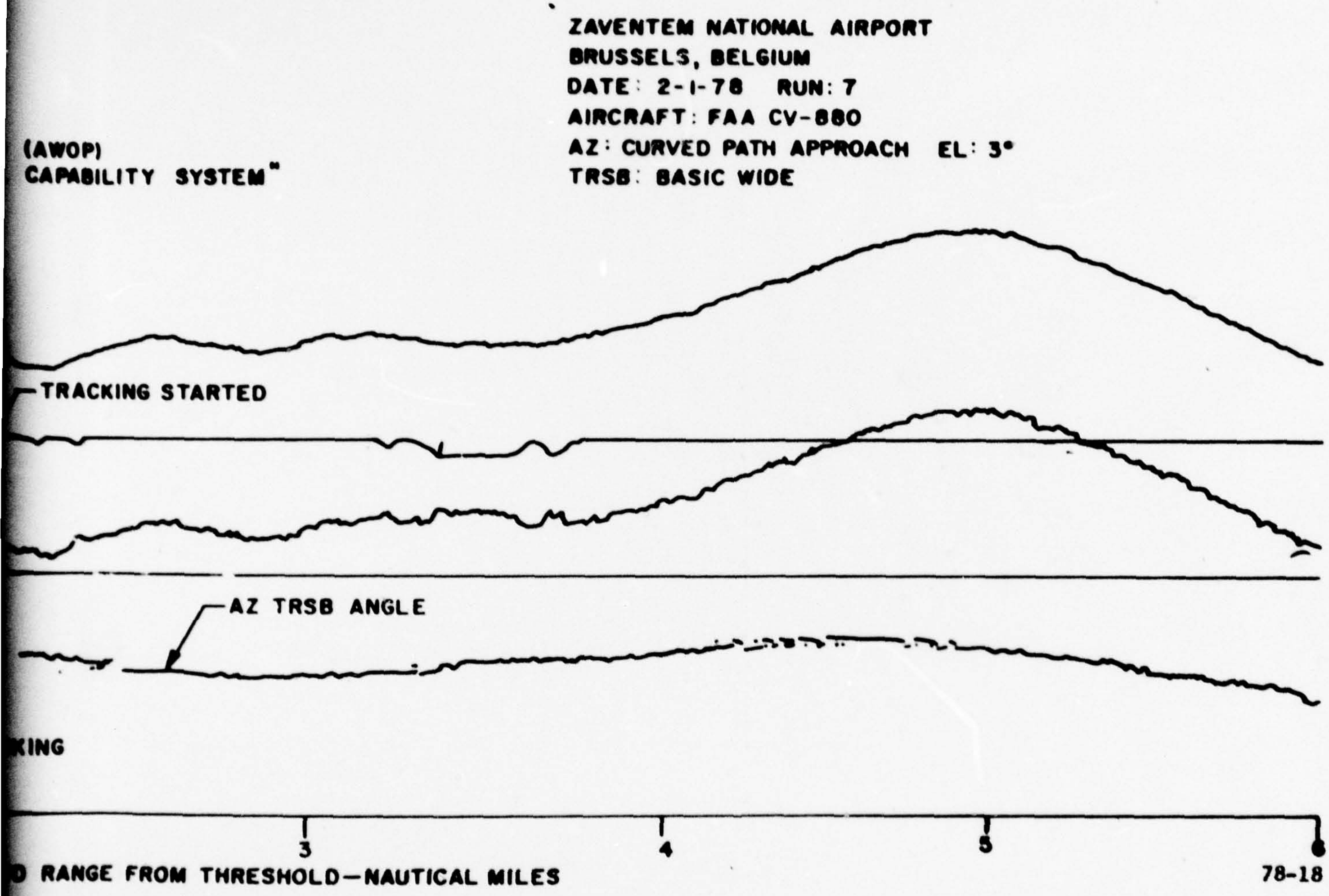


FIGURE 17. ANALOG DATA PLOT OF 2/



. ANALOG DATA PLOT OF 2/1/78, CV-880, RUN 7

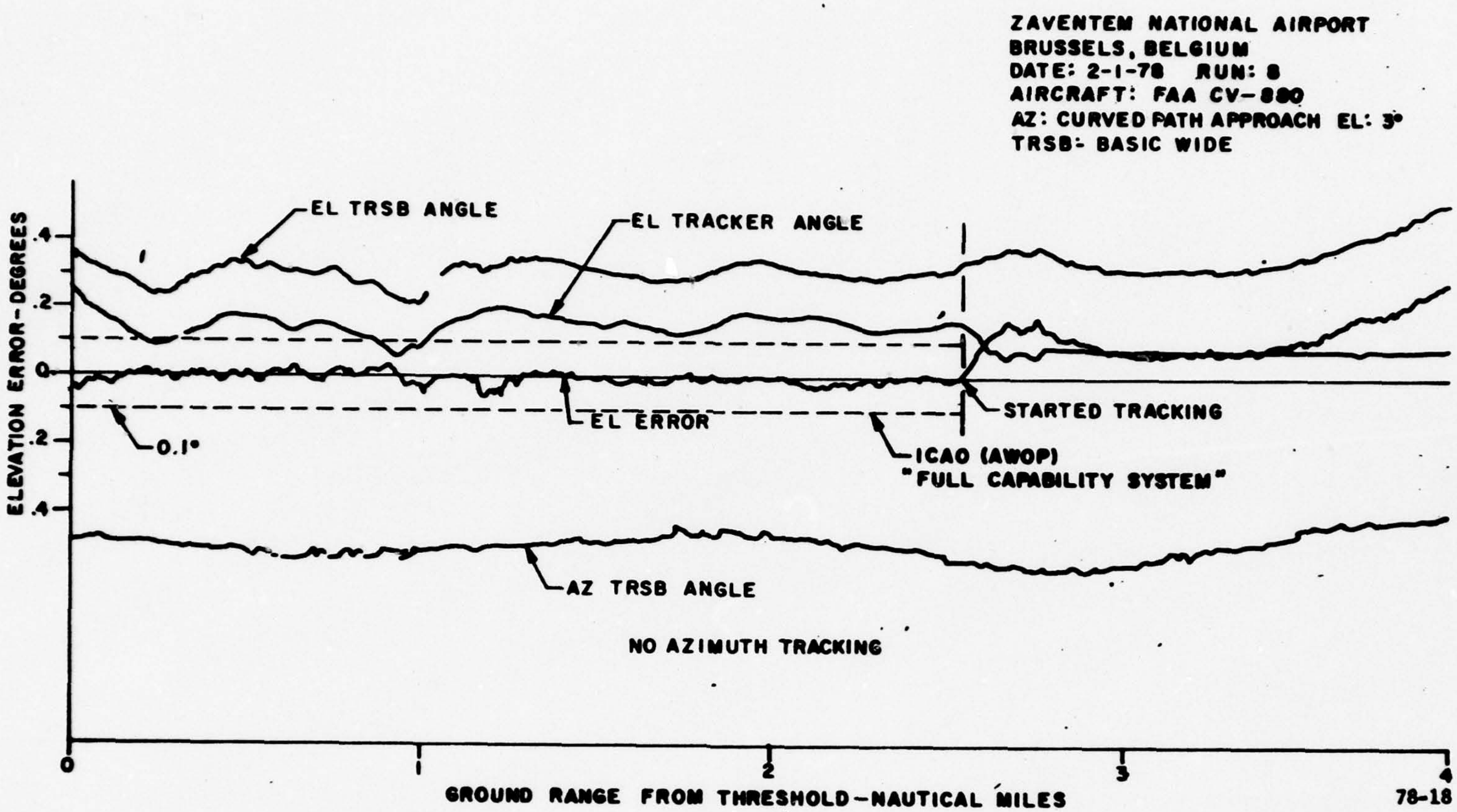


FIGURE 18. ANALOG DATA PLOT OF 2/1/78, CV-880, RUN 8

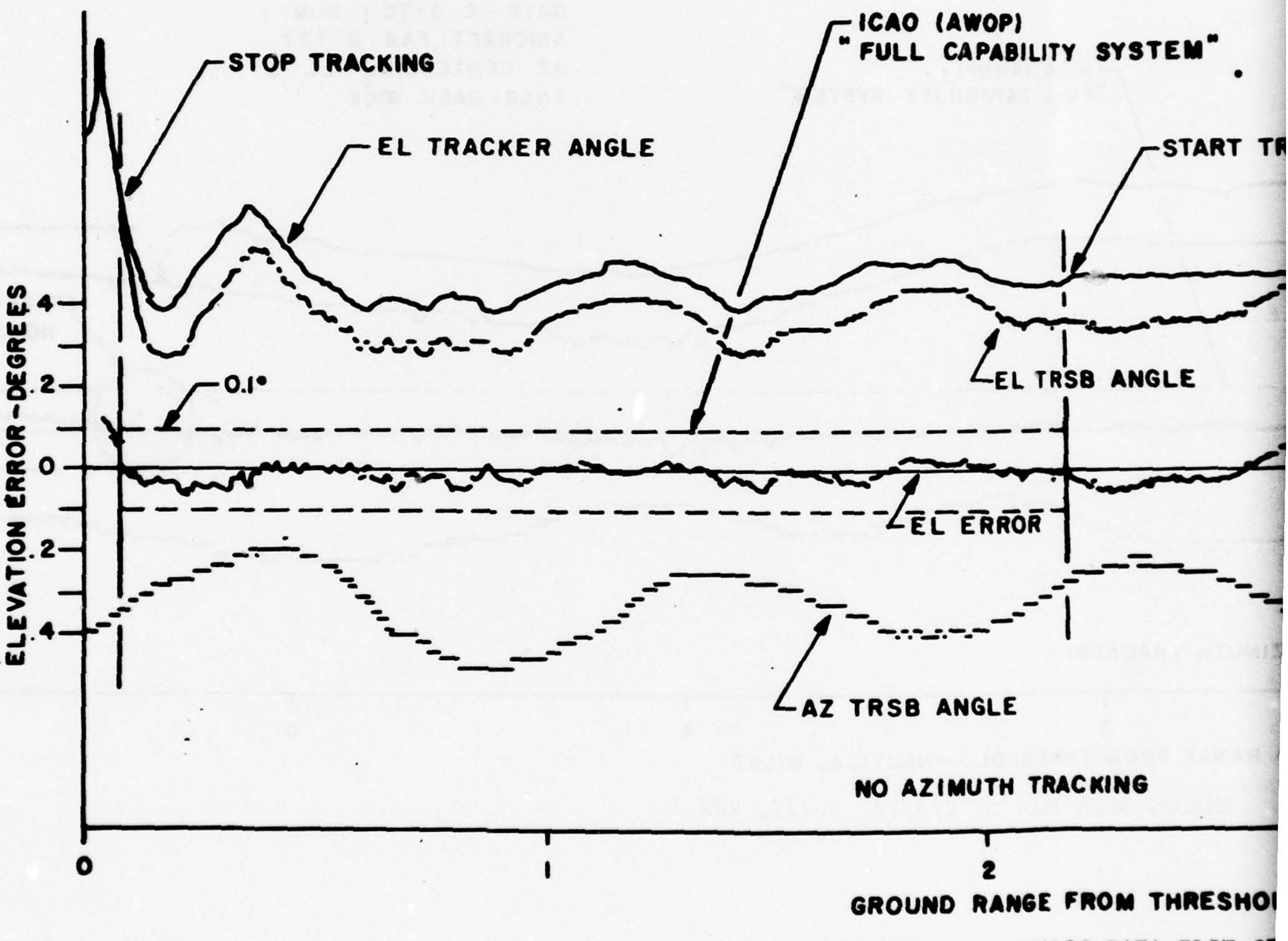
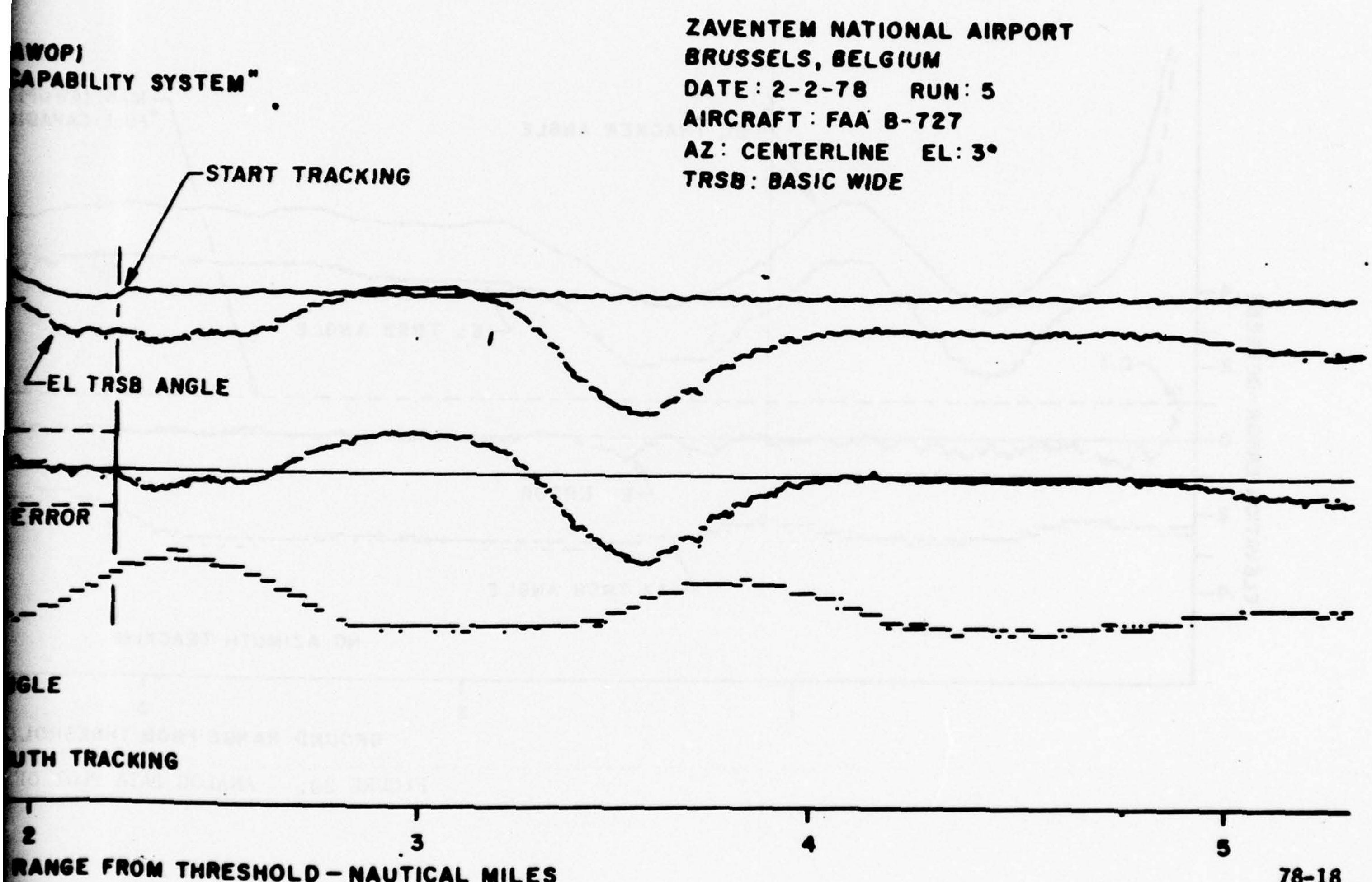


FIGURE 19. ANALOG DATA PLOT OF



ANALOG DATA PLOT OF 2/2/78, B-727, RUN 5

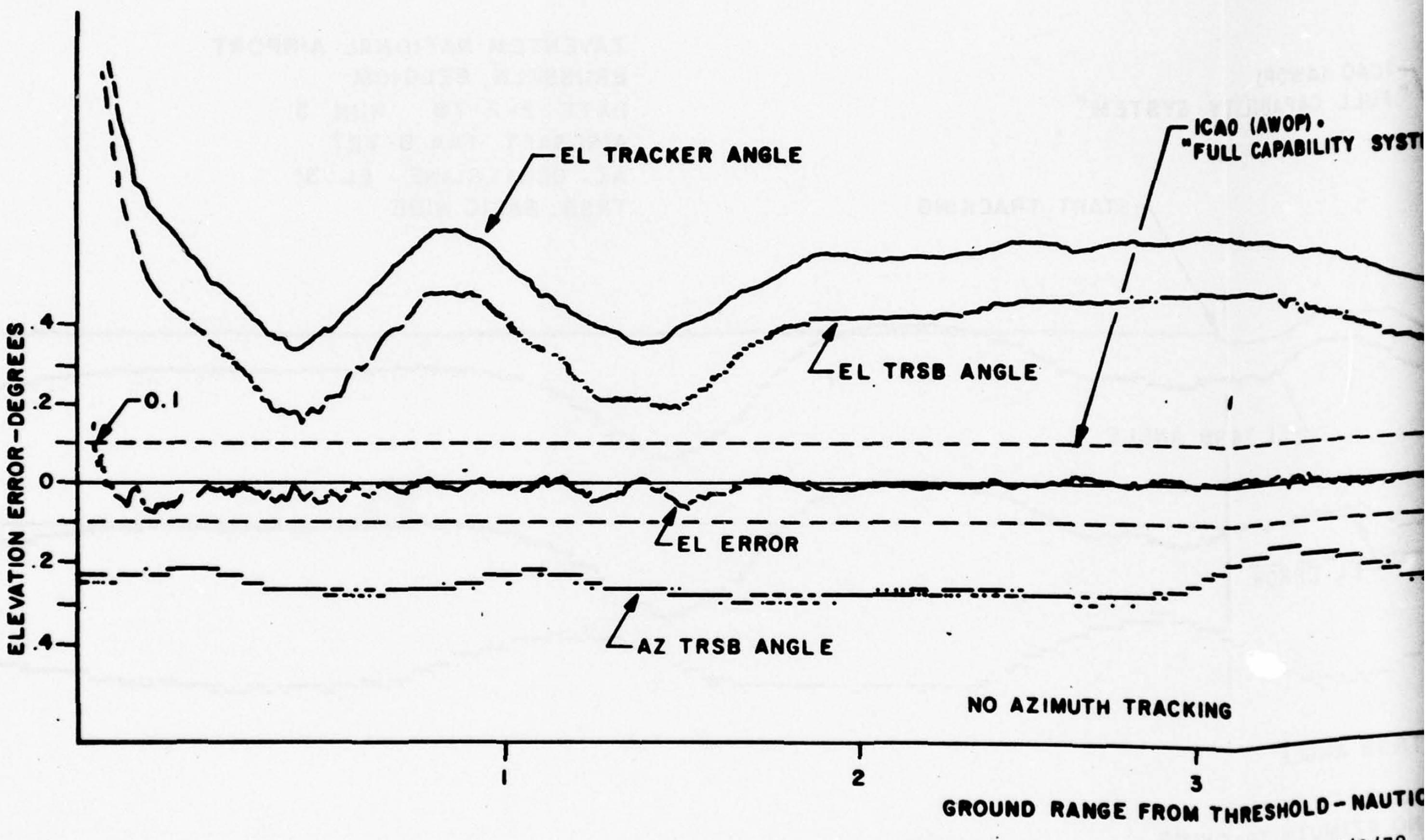
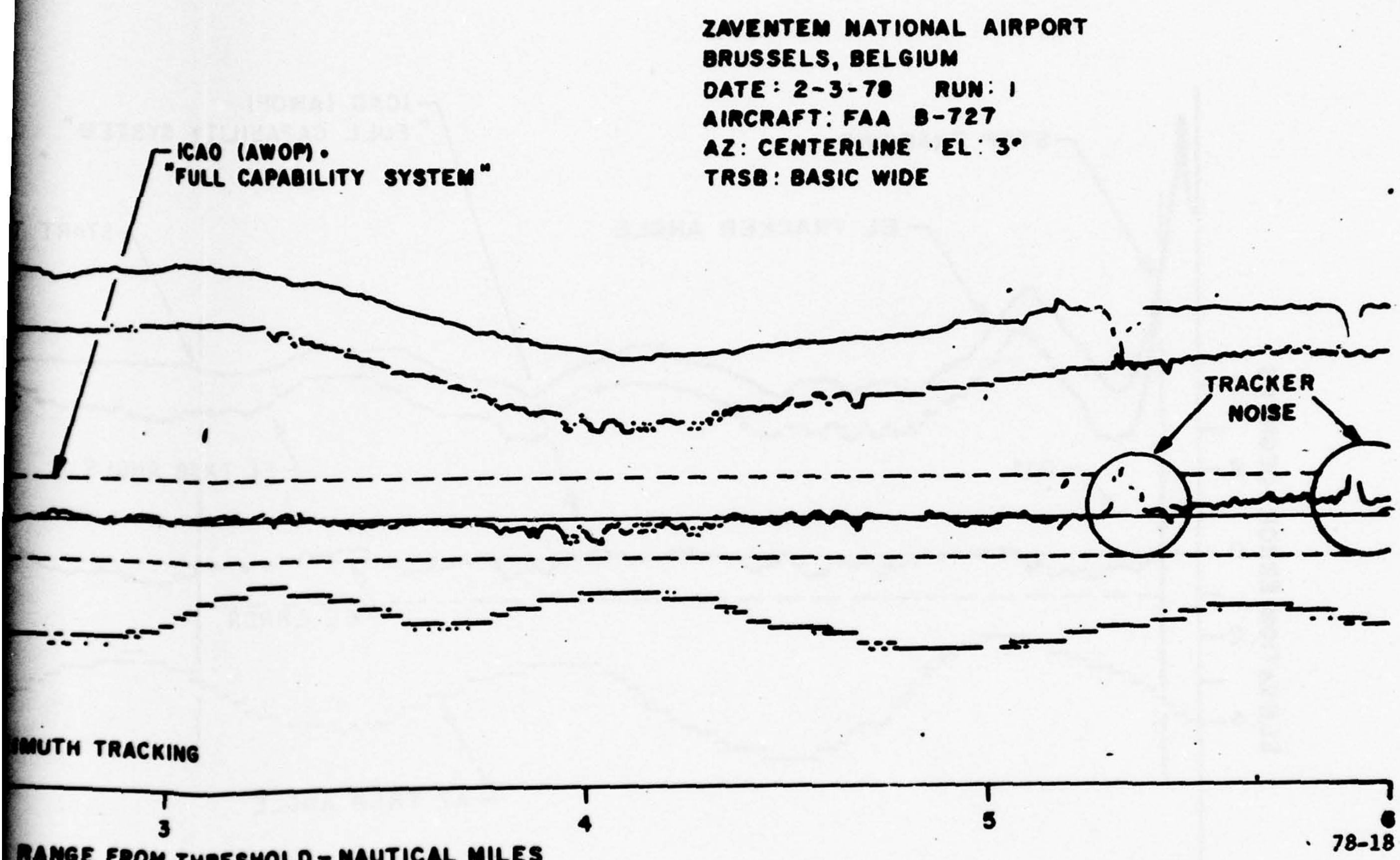


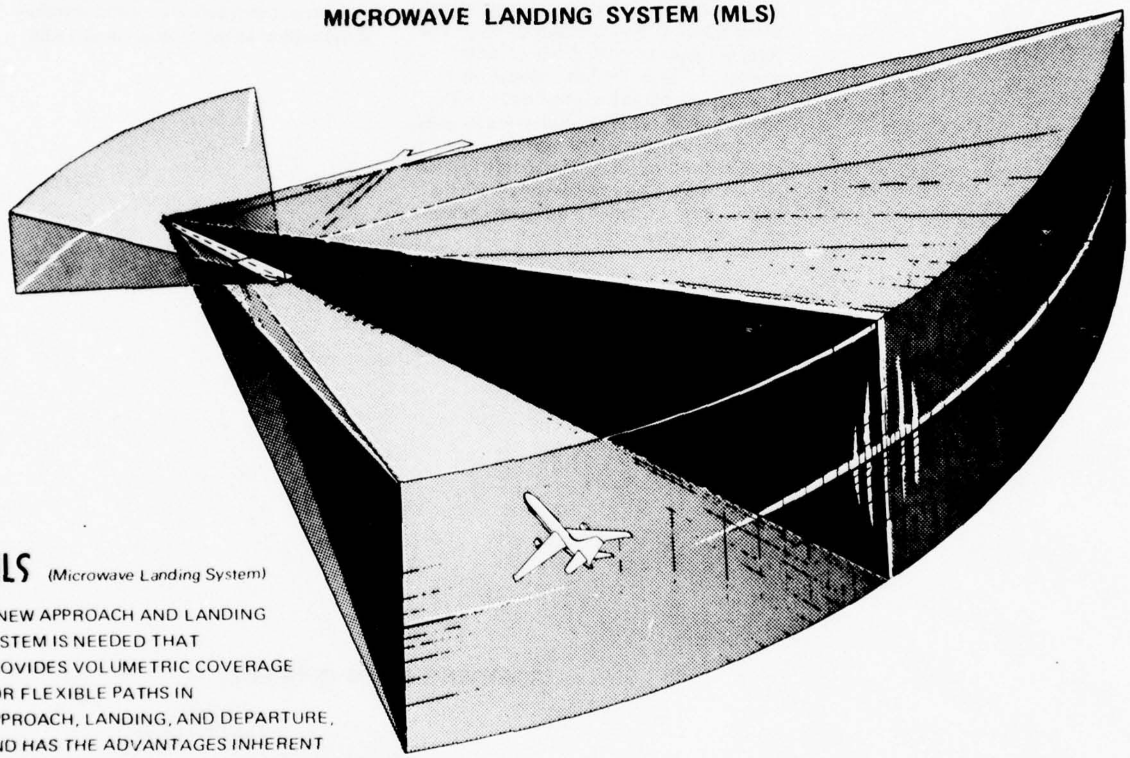
FIGURE 20. ANALOG DATA PLOT OF 2/3/78,



ANALOG DATA PLOT OF 2/3/78, B-727, RUN 1

APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



MLS (Microwave Landing System)

A NEW APPROACH AND LANDING SYSTEM IS NEEDED THAT PROVIDES VOLUMETRIC COVERAGE FOR FLEXIBLE PATHS IN APPROACH, LANDING, AND DEPARTURE, AND HAS THE ADVANTAGES INHERENT WITH OPERATING AT MICROWAVE FREQUENCIES

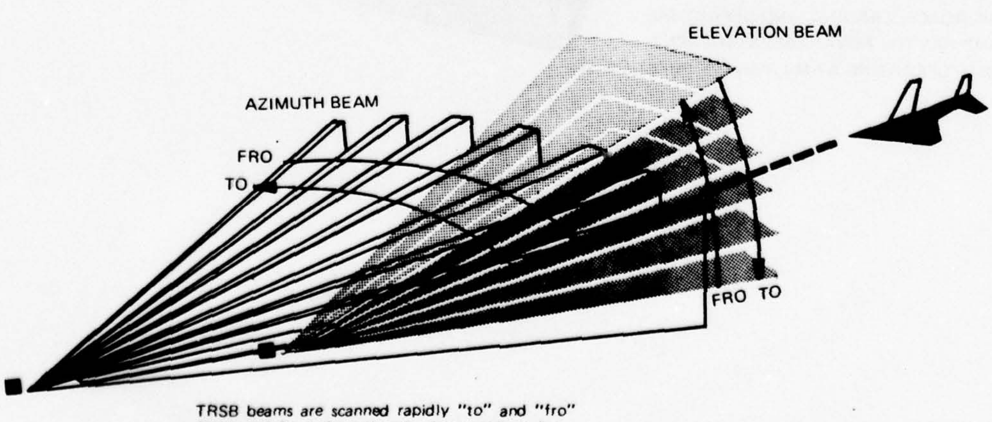
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no form of modulation. Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. In each complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and channelization capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore **is not critical to the description of TRSB.**

SCANNING BEAM CONCEPT



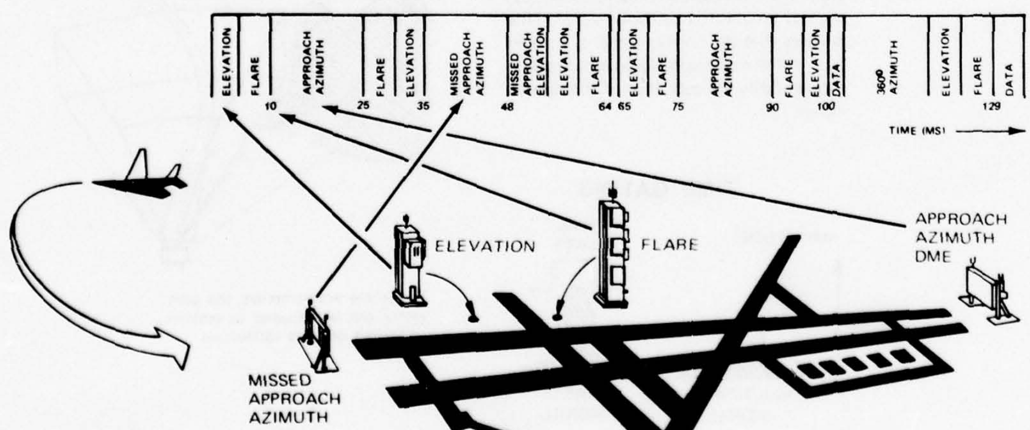
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a *minimum data rate* (*minimum* number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° *azimuth guidance with a* 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional future functions.

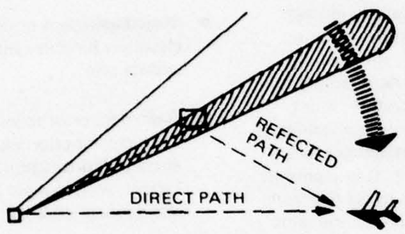


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

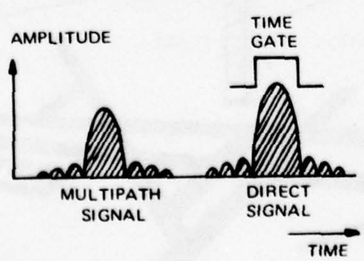
THERE ARE TWO TYPES OF MULTIPATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, around the desired guidance signal. This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



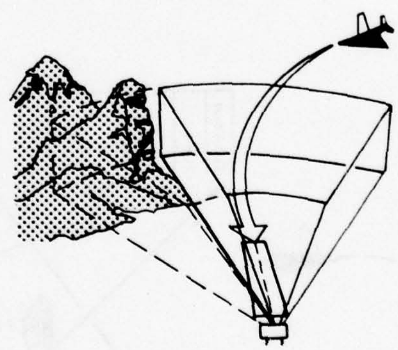
Time gating ensures that the correct signal is tracked, not the reflected one

IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent undesired obstacle reflections

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

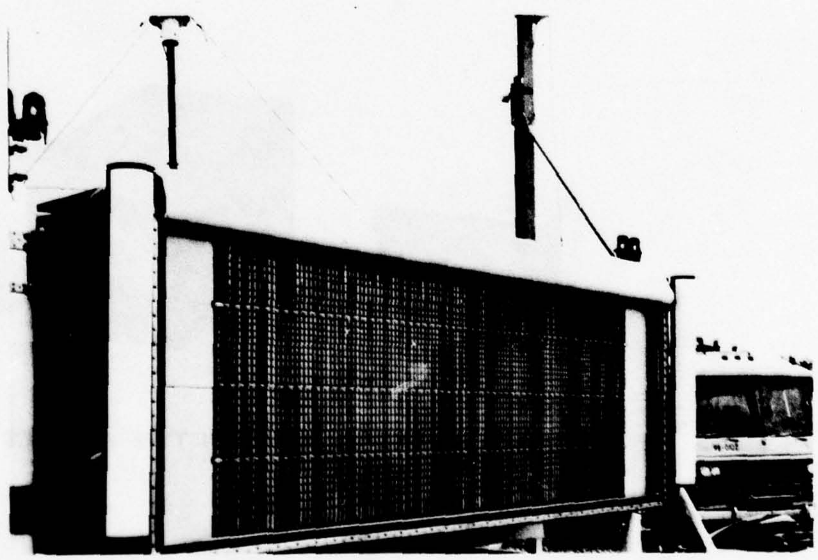
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals-in-space of uniform quality in all airport environments.

NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ±60	Approach Azimuth; Long Runways
Azimuth	2	Up to ±60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ±60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.
** **See multipath discussion.**



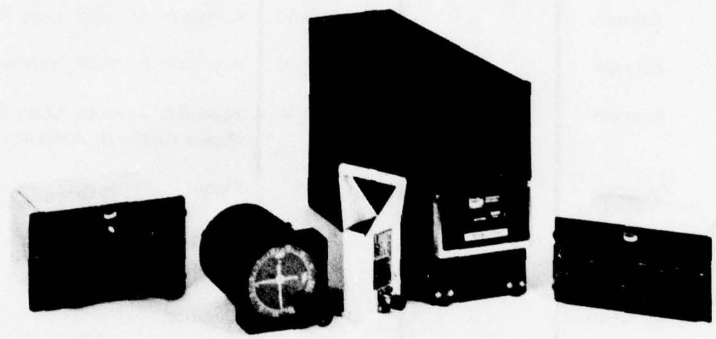
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

AIRBORNE RECEIVER DESIGNS ALSO STRESS THE MODULARITY CONCEPT. Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing guidance at the lowest cost, an aircraft needs only an antenna and a basic receiver-processor unit operating with existing ILS displays. An air-transport category aircraft equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational capabilities provided by TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation subsystems and decodes the auxiliary data for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual readout of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An optional airborne computer would be used to generate curved or segmented approaches based on TRSB position information.



AIRLINE TYPE AVIONICS

GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

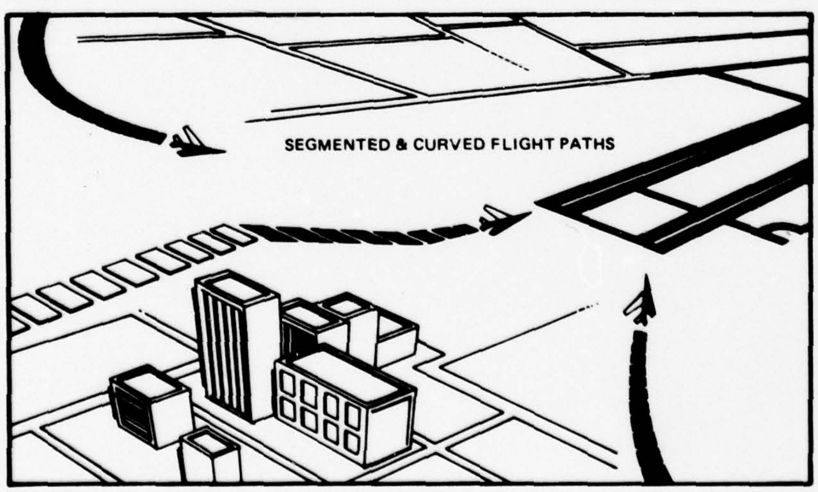
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver-processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout

APPENDIX B

AVIATION WEEK REPRINT

REPRINTED FROM: AVIATION WEEK & SPACE TECHNOLOGY February 13, 1978

Competing MLS Systems Complete Brussels Tests

By Robert R. Ropelewski

Brussels—Federal Aviation Administration has completed four days of demonstrations here of its time reference scanning beam microwave landing system, with initial results suggesting there was little difference in performance between the U. S. system and the British Doppler MLS system, which was demonstrated here earlier.

The Brussels international site has been much disputed by proponents of the U. S. MLS concept and those of the British Doppler concept, as far as the predicted performances of the two systems at Brussels International Airport were concerned. With both systems now having been evaluated there, program officials on the U. S. side, at least, are acknowledging that the results appear to be roughly the same for both systems.

The FAA demonstrations, which took place here from Jan. 30 through Feb. 2, included 47 MLS approaches at both Brussels International and Gosselies airport at Charleroi, a few miles to the east. Two FAA aircraft, a Boeing 727 and a Convair 880, were used in the presentations.

The CV 880, which was equipped with an automatic landing system and an onboard computer for curved MLS approaches, accomplished 32 of the 47 approaches. All of the CV 880 approaches—23 of which were made at Brussels and nine at Gosselies—terminated with an automatic landing.

In addition to the demonstrations of the FAA system, U. S. and British technicians exchanged data on the performance of their respective systems at Brussels, and a British Civil Aviation Authority Hawker Siddeley HS 748 transport made several approaches on the FAA/Bendix MLS system to evaluate the performance of the U. S. system independently. FAA officials indicated here last week that they believed both sides had all the necessary data to evaluate properly the performance of the U. S. time reference scanning beam system at Brussels.

For the FAA demonstrations, the MLS systems at Brussels and Gosselies were both Bendix supplied. The system installed at Brussels was the "basic narrow" configuration for normal Cat. 2 operations, used in this case in conjunction with a Cardion Electronics distance measuring equipment (DME) transmitter for precision distance information down to touchdown. The basic narrow system uses a 2 deg. beamwidth phased array azimuth antenna and a 1.5 deg. phased array elevation antenna.

The Gosselies installation was a less accurate (and lower cost) "small community" Cat. 1 system with a 3 deg. phased array azimuth antenna and a 2 deg. phased array elevation antenna. No DME was installed at Gosselies.

Both systems were set up relatively quickly after their arrival in Belgium. FAA technicians said the mechanical installation of the system at Gosselies was finished in 1 hr. 15 min., and the FAA Convair 880 made its initial approach and automatic landing with the system a day and a half after the equipment was delivered to the Gosselies airport.

This AVIATION WEEK & SPACE TECHNOLOGY editor observed two MLS approaches at Gosselies aboard the FAA 727 aircraft, both approaches terminating with a low pass down the runway. First of these was a manually flown approach on a 3 deg. glideslope with a 2 deg. left offset—meaning an angling approach that had to be corrected on short final to align the aircraft with the runway centerline.

The second approach was a coupled (automatic) approach on the runway centerline with a 4 deg. glideslope. Gosselies weather was poor at the time, and in both cases the runway approach lights appeared only when the aircraft had descended to 200 ft. above ground level, and the runway lights themselves became visible at just under 150 ft. above ground level.

Because of the 2 deg. offset on the first approach, there was no reference with which to judge visually the accuracy of the approach. In the second approach, however, the aircraft broke from the clouds at 150 ft. aligned accurately with the centerline. The 727 drifted slightly to the left of centerline after the crew took over manually to initiate the low-pass and go-around, but this was reflected on the MLS course deviation indicator on the instrument panel and flight director.

A low fuel state and heavy traffic at Brussels International allowed the observation of only one curved approach and automatic landing in the CV 880 at Brussels. This approach was effected with no apparent discrepancies, and the touchdown appeared to be precisely on centerline.

The 880 was equipped for flight test purposes with a PDP 11/34 digital computer which provided guidance signals to the aircraft's Collins FCS 110F flight director during the curved portion of the approach. The curved portion was preprogramed on a floppy disc.

The approach began from a position about 7-8 mi. abeam the runway with the aircraft flying downwind at 3,750 ft. The aircraft appeared to enter MLS beam coverage at about the 45 deg. azimuth radial, about 5 mi. downwind from the runway threshold, still heading downwind.

A left descending turn was then initiated toward the extended runway centerline, with the aircraft intercepting the extended centerline about 8-9 mi. from the runway threshold, 2,000 ft. altitude, and heading toward the runway. Once the elevation signal for a 3 deg. glideslope was intercepted, the aircraft tracked the system down to a full automatic landing on centerline with no apparent deviations.

In a repeat of a test imposed on the British Doppler MLS system, two Belgian air force Lockheed C-130 transports were parked on a taxiway where they would be between the approaching aircraft and the elevation transmitter antenna. Wheel positions of the aircraft had been marked on the taxiway during the earlier British demonstrations at Brussels, and the C-130 positioning was thus exactly the same for the FAA demonstrations.

FAA and Bendix technicians said no elevation signal deviation could be detected on those approaches flown on a 4 deg. glideslope, and "very little" deviation was detected on those approaches flown on a 3 deg. glideslope.

While some evidence of signal masking was noted on the 2 deg. glideslope approaches, in which the tail of one of the C-130s blanked out the signals to the approaching aircraft in one spot, FAA officials said there were no autopilot disconnects as a result of the signal masking, and induced errors were relatively small and still within the limits set by International Civil Aviation Organization.

Bendix engineers said the same situation was true for the British Doppler MLS when it was evaluated at Brussels.

The FAA demonstrations at Brussels and Gosselies followed two days of MLS demonstrations at Kjevik airport in Kristiansand, Norway, during which approximately 35 approaches were flown on both the small community and basic narrow MLS systems. Additionally, several constant altitude overflights at 2,000 ft. were effected to demonstrate the system's elevation (glideslope) coverage up to 20 deg.

FAA officials said a Norwegian flight check aircraft reported receiving the signals from the FAA MLS system at a distance of 70 naut. mi.

Approaches flown at Kristiansand were the same type as those flown there earlier with the British Doppler MLS system. These included straight-in approaches and approaches on the 1, 2 and 3 deg. MLS radials on glideslopes of 2, 3 and 4 deg. The basic narrow and small community system configurations were colocated for the FAA demonstrations, and program officials said there were no deviations between the two.

As in the case of the Brussels demonstrations, FAA and Bendix technicians noted that there was little difference in the performance of the time-reference scanning beam and the Doppler system at Kristiansand, based on the British data they had seen.

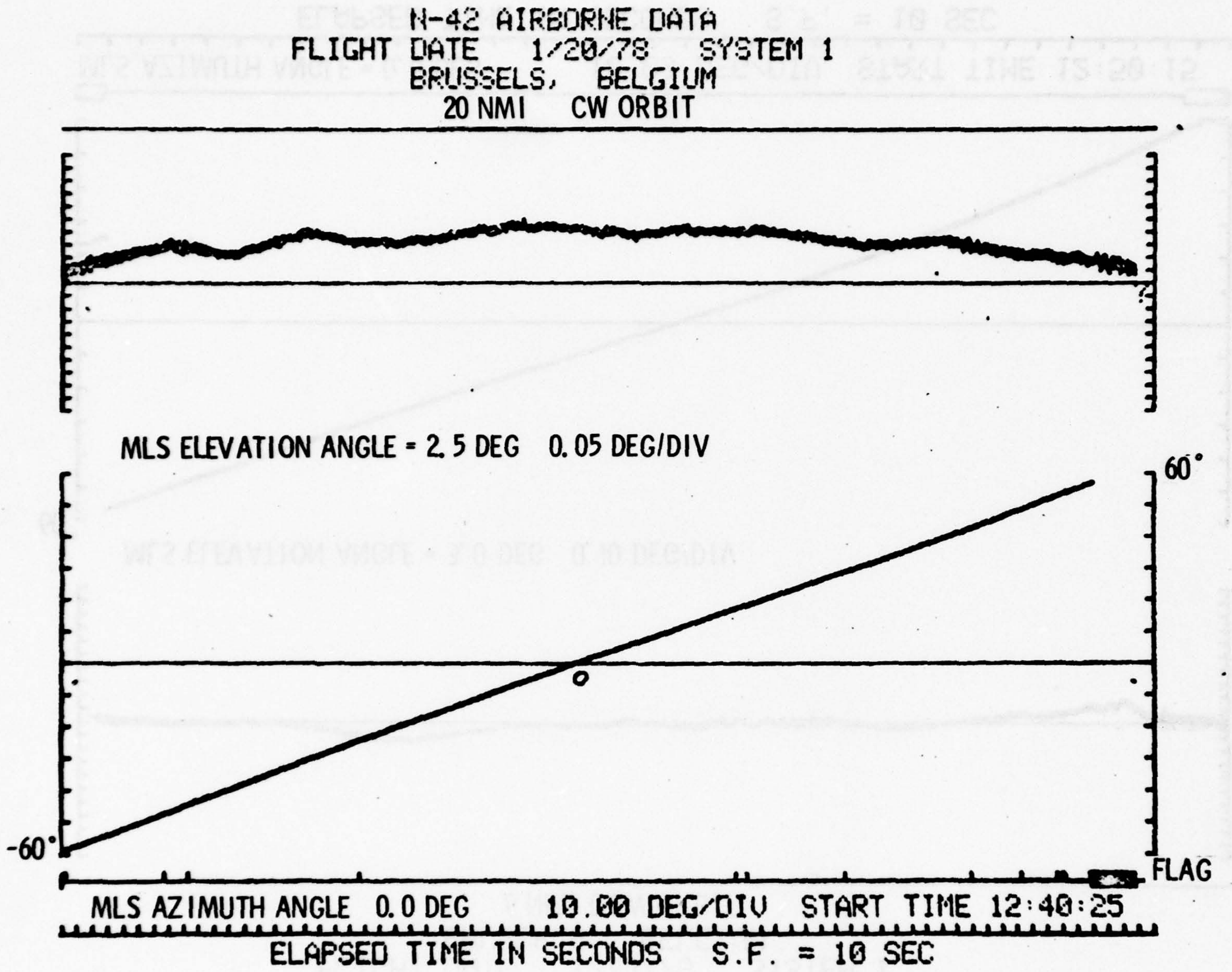
"We encountered about the same interference and the same reflections," a Bendix engineer said. Both systems, he said, had performed well within ICAO specifications. An FAA MLS specialist conceded that for both the time-reference scanning beam system and the Doppler system, overflights of the azimuth antenna by departing aircraft result in much less beam distortion than on existing instrument landing systems (ILS).

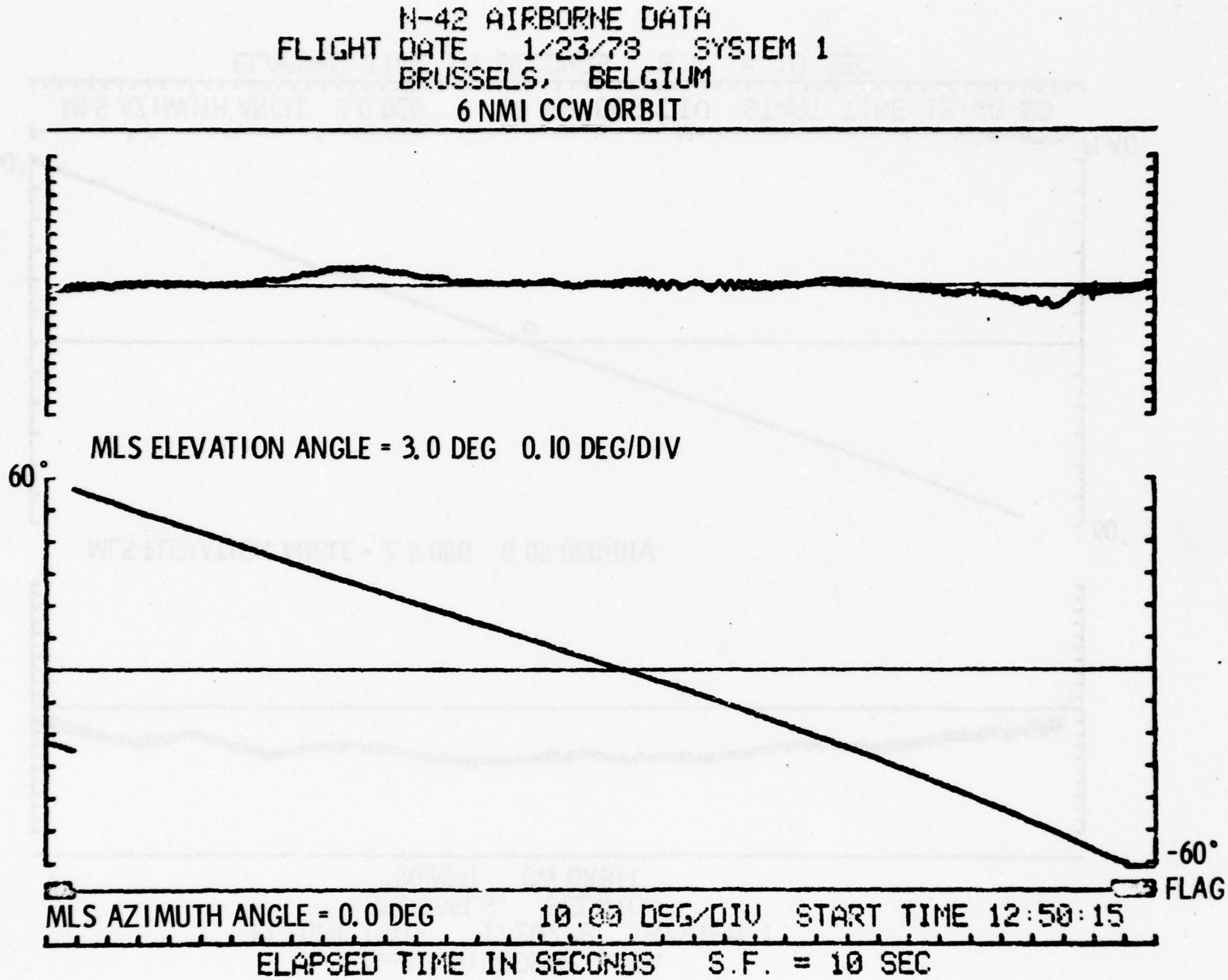
While the FAA's Convair 880 returned to the U. S. last week, the agency's 727 left Brussels for Dakar, Senegal, where demonstrations of the small community MLS system will be made. From there, the aircraft and system will go on to Nairobi, Kenya, and Shiraz, Iran, for additional demonstrations before returning to the U. S.

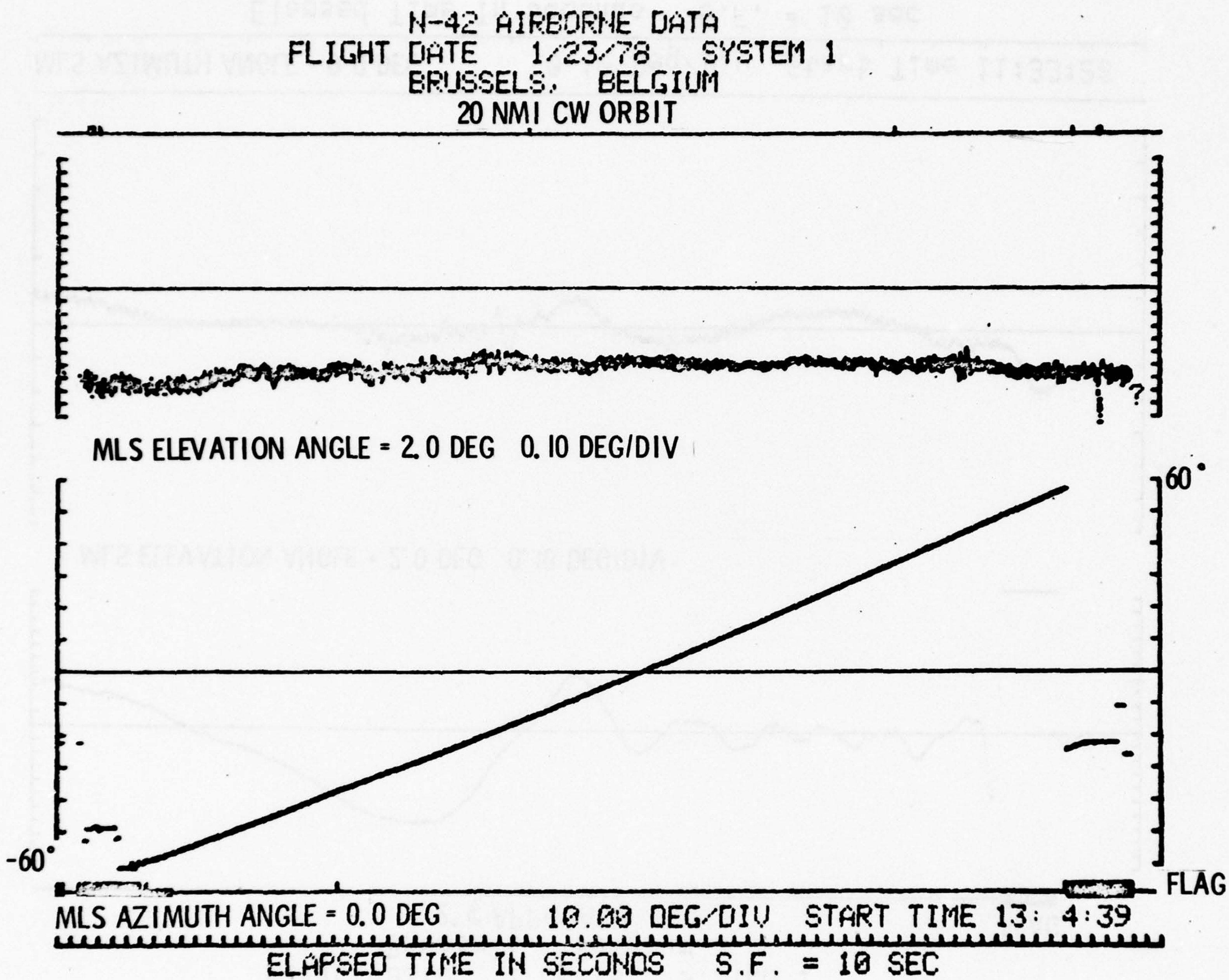
Side-by-side demonstrations of both the U. S. and the British systems are now scheduled for late March and early April at Montreal, prior to the ICAO general meeting in Montreal on Apr. 4 when the selection of one of the two systems for a worldwide standard is scheduled to be made.

APPENDIX C

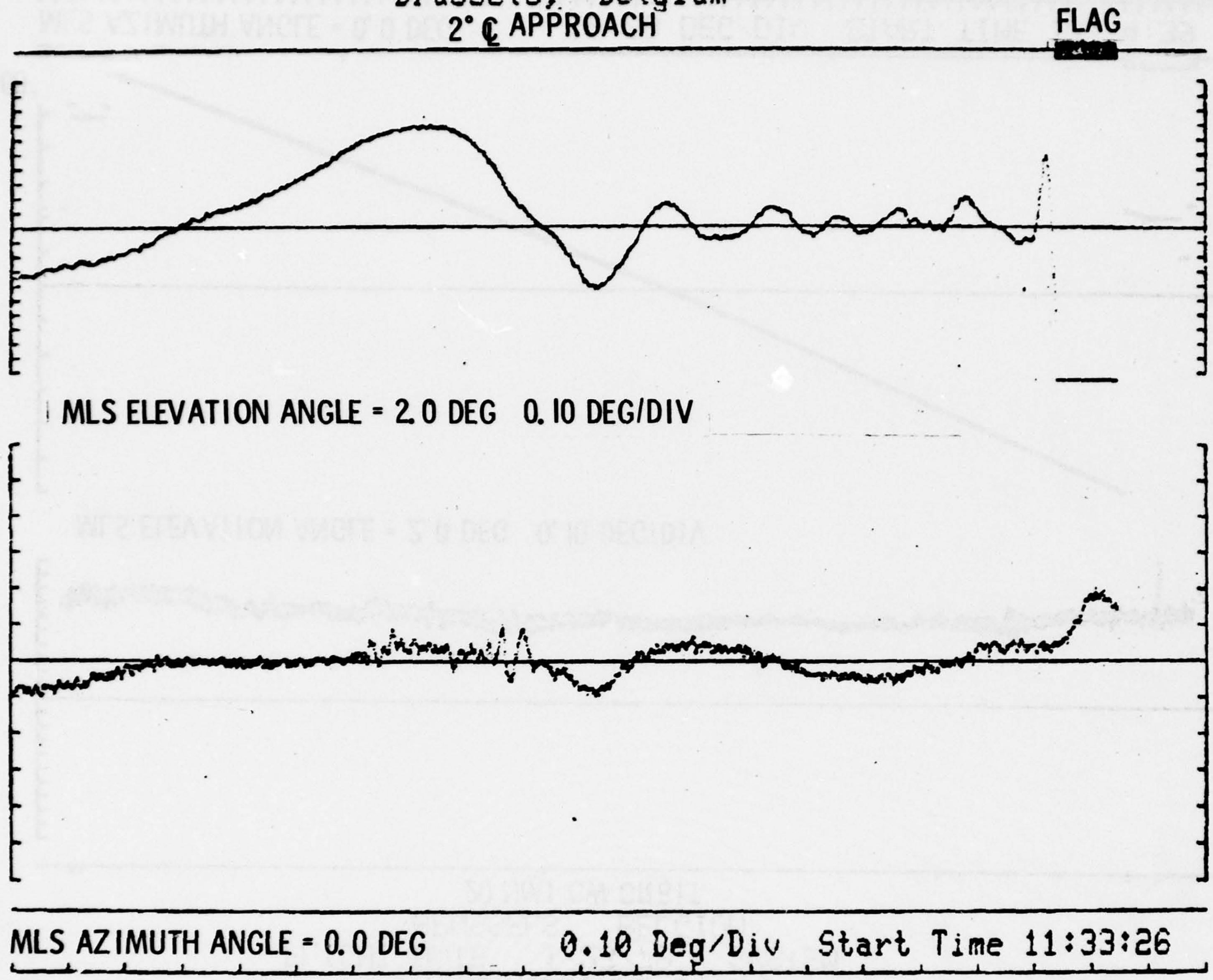
U.S. DIGITAL TRSB DATA


N-42 AIRBORNE DATA
FLIGHT DATE 1/20/78 SYSTEM 1
BRUSSELS, BELGIUM
20 NMI CW ORBIT
MLS ELEVATION ANGLE = 2.5 DEG 0.05 DEG/DIV
60°
0
-60°
FLAG
MLS AZIMUTH ANGLE 0.0 DEG 10.00 DEG/DIV START TIME 12:40:25
ELAPSED TIME IN SECONDS S.F. = 10 SEC

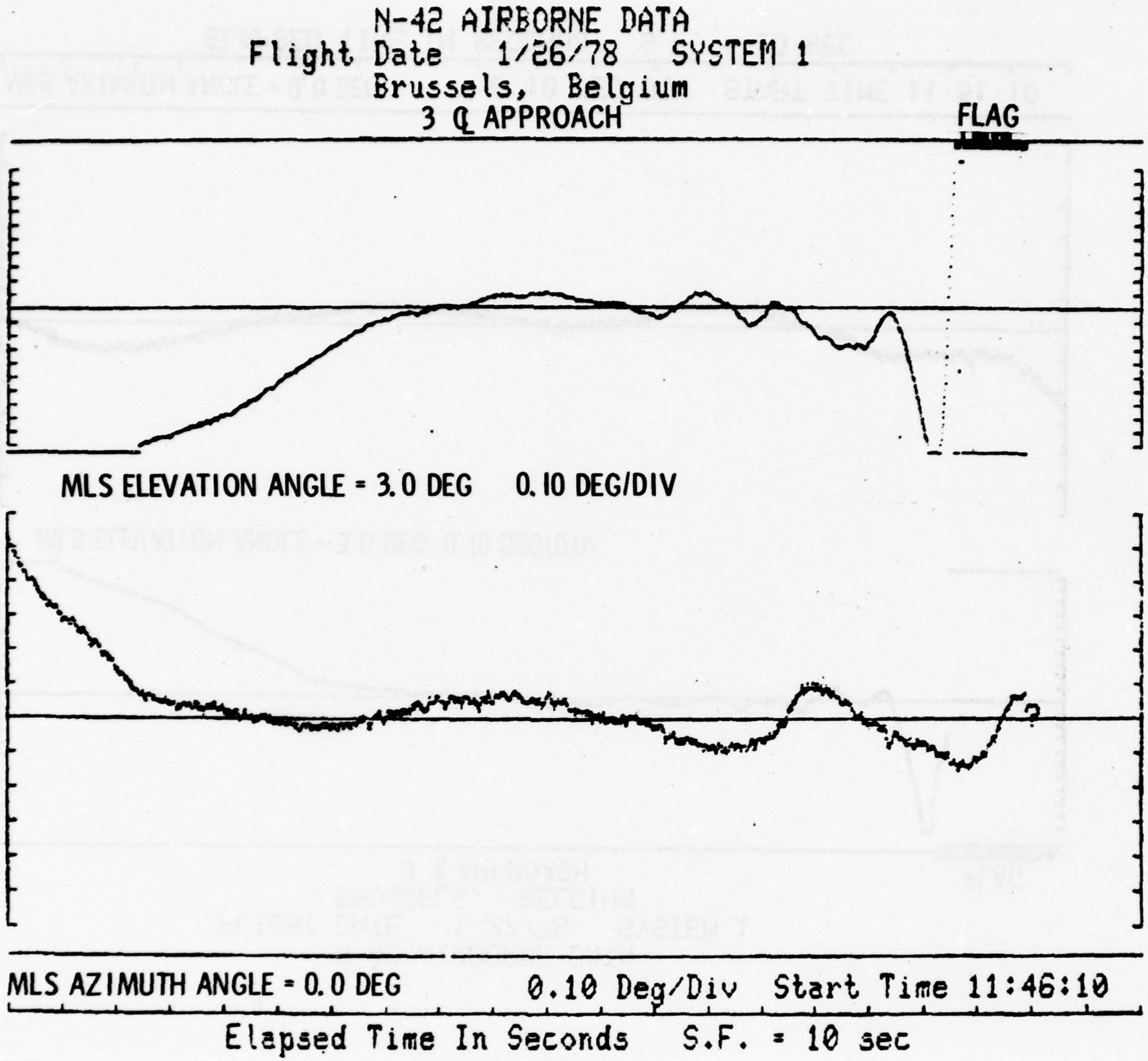

N-42 AIRBORNE DATA
FLIGHT DATE 1/23/78 SYSTEM 1
BRUSSELS, BELGIUM
6 NMI CCW ORBIT
MLS ELEVATION ANGLE = 3.0 DEG 0.10 DEG/DIV
60°
-60°
FLAG
MLS AZIMUTH ANGLE = 0.0 DEG 10.00 DEG/DIV START TIME 12:50:15
ELAPSED TIME IN SECONDS S.F. = 10 SEC


N-42 AIRBORNE DATA
FLIGHT DATE 1/23/78 SYSTEM 1
BRUSSELS, BELGIUM
20 NMI CW ORBIT
?
MLS ELEVATION ANGLE = 2.0 DEG 0.10 DEG/DIV
60°
-60°
FLAG
MLS AZIMUTH ANGLE = 0.0 DEG 10.00 DEG/DIV START TIME 13: 4:39
ELAPSED TIME IN SECONDS S.F. = 10 SEC

N-42 AIRBORNE DATA
Flight Date 1/26/78 SYSTEM 1
Brussels, Belgium
2° ℄ APPROACH

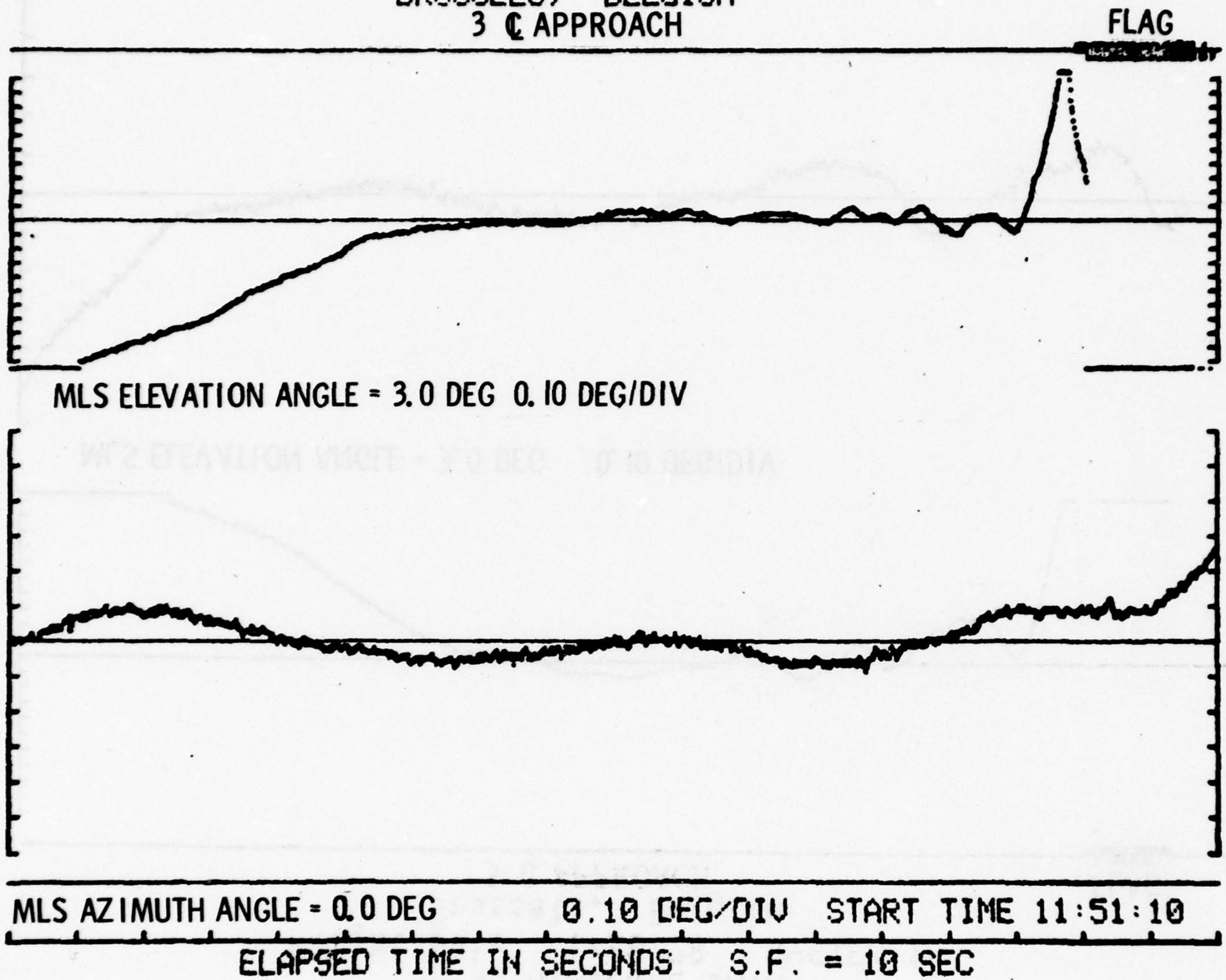


Elapsed Time In Seconds S.F. = 10 sec



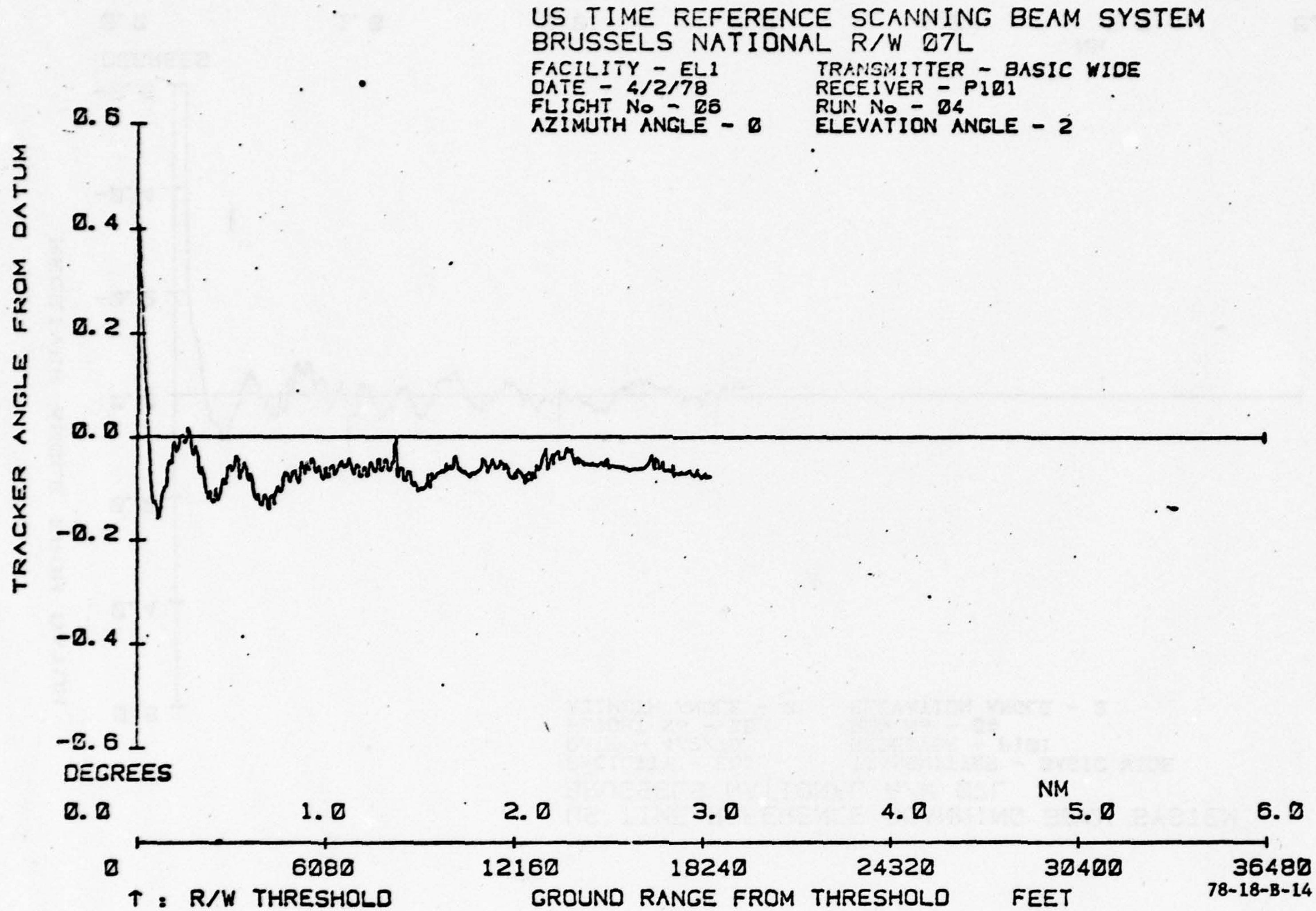
N-42 AIRBORNE DATA
Flight Date 1/26/78 SYSTEM 1
Brussels, Belgium
3 ℄ APPROACH
FLAG
MLS ELEVATION ANGLE = 3.0 DEG 0.10 DEG/DIV
MLS AZIMUTH ANGLE = 0.0 DEG 0.10 Deg/Div Start Time 11:46:10
Elapsed Time In Seconds S.F. = 10 sec

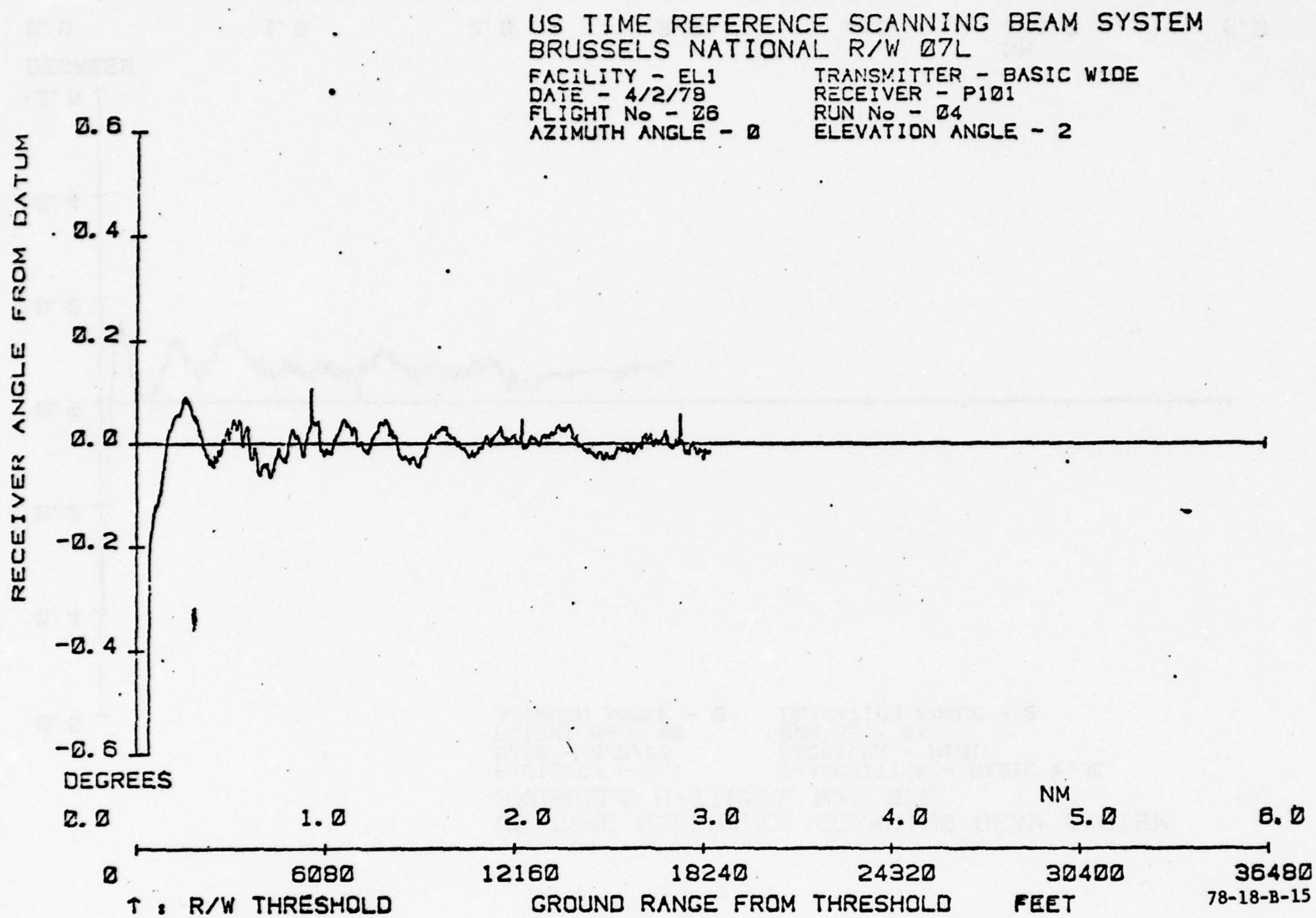
N-42 AIRBORNE DATA
FLIGHT DATE 1/27/78 SYSTEM 1
BRUSSELS, BELGIUM
3 ℄ APPROACH

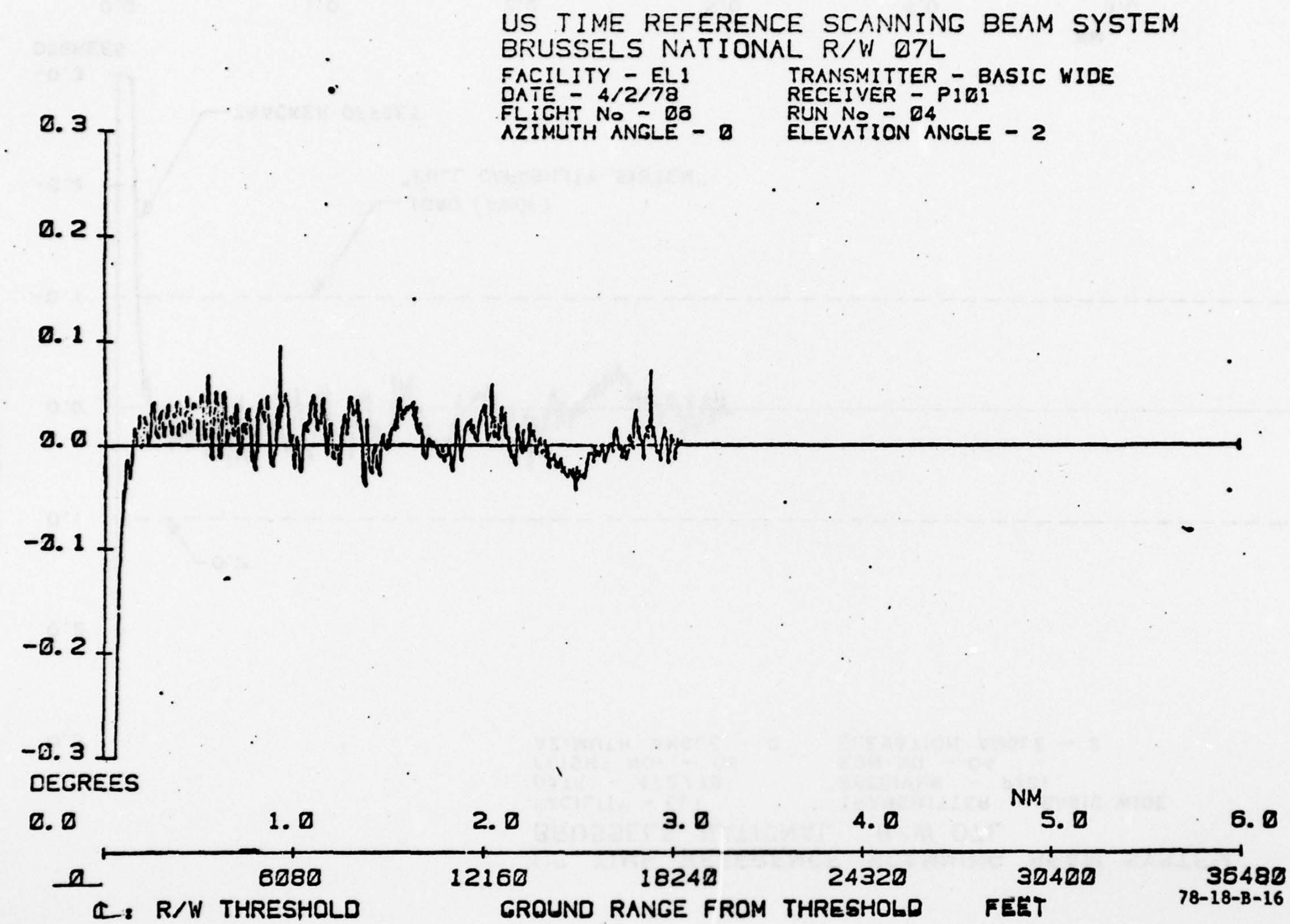


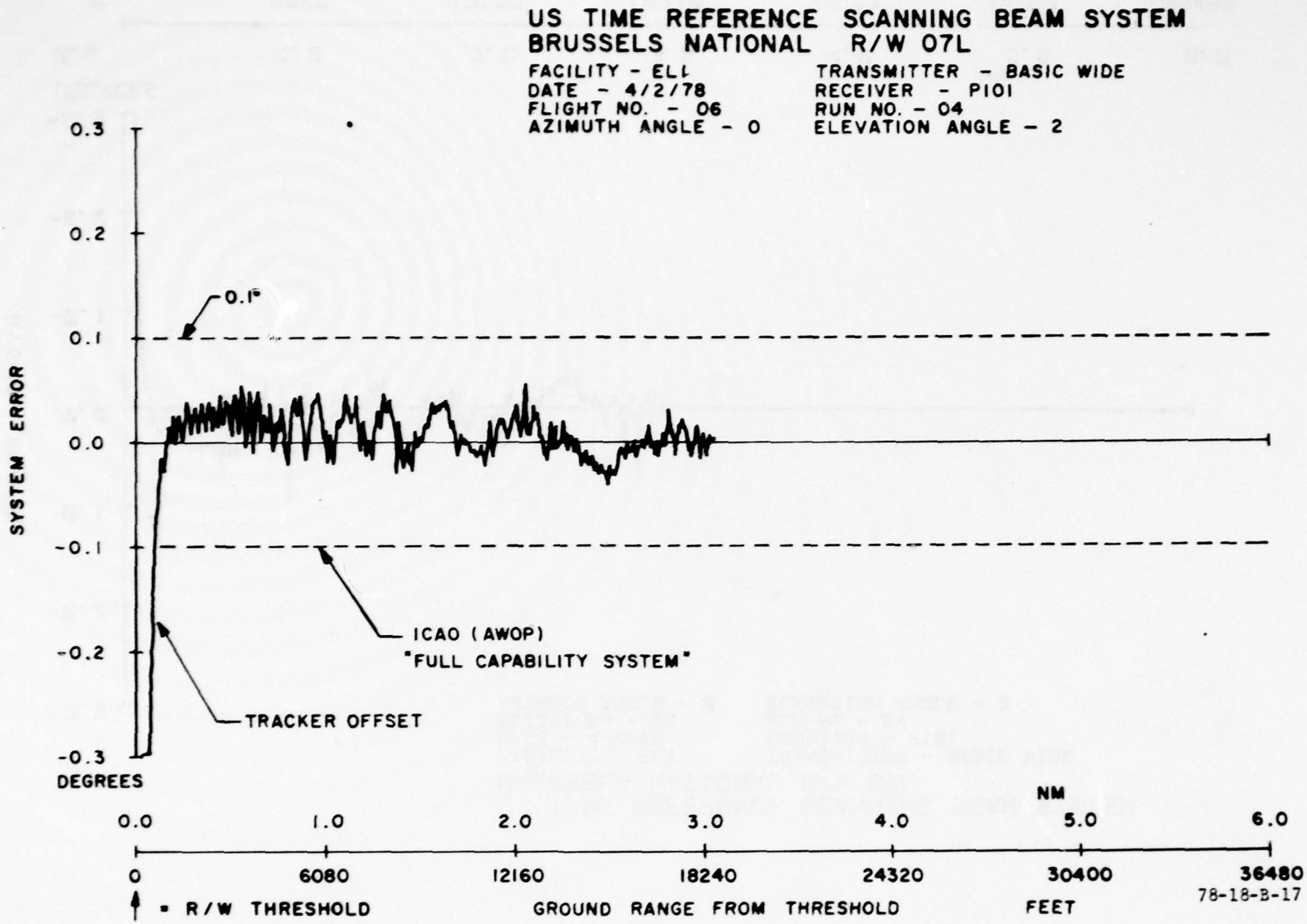
APPENDIX D

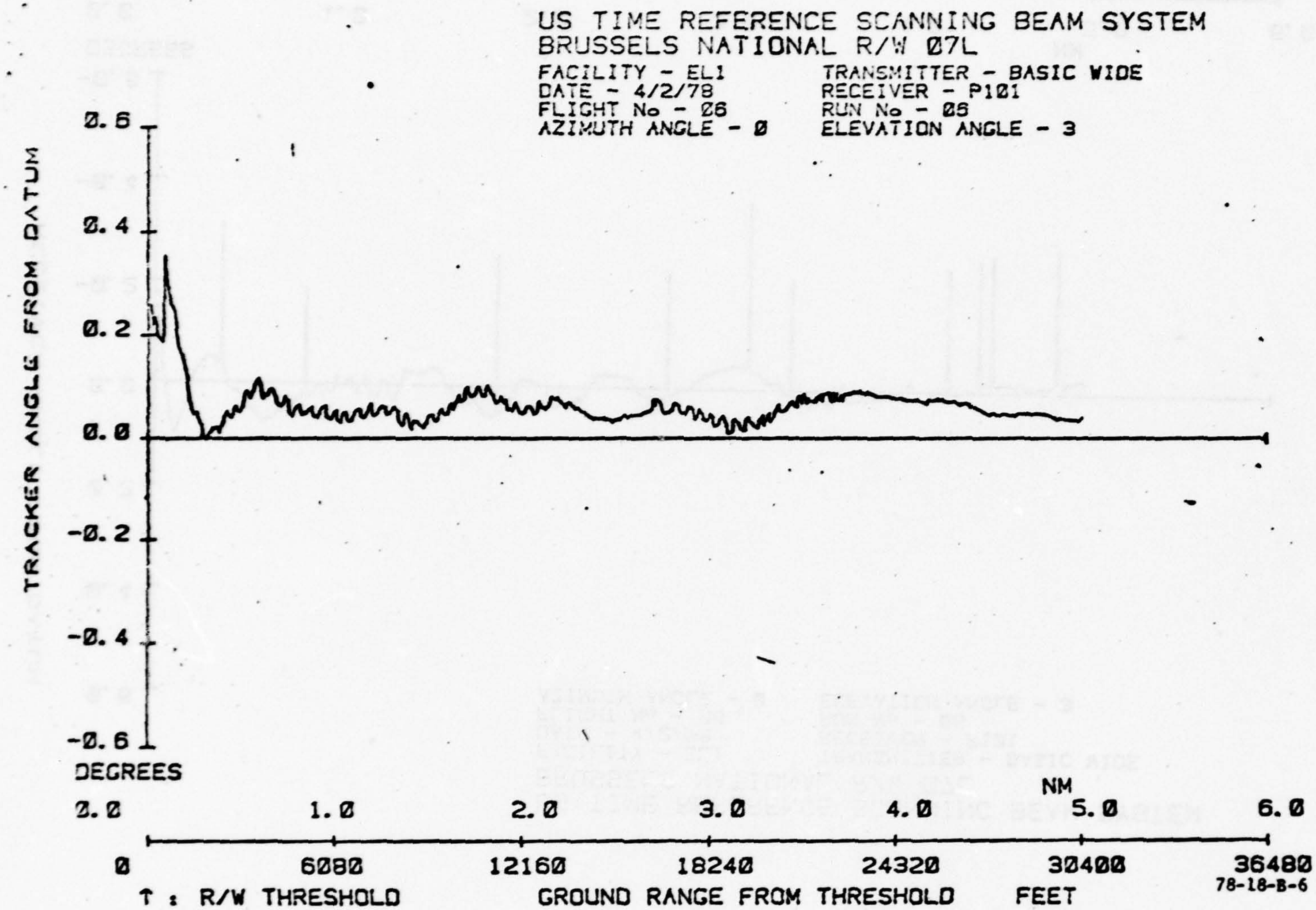
TRSB DATA COLLECTED BY UK/CAA

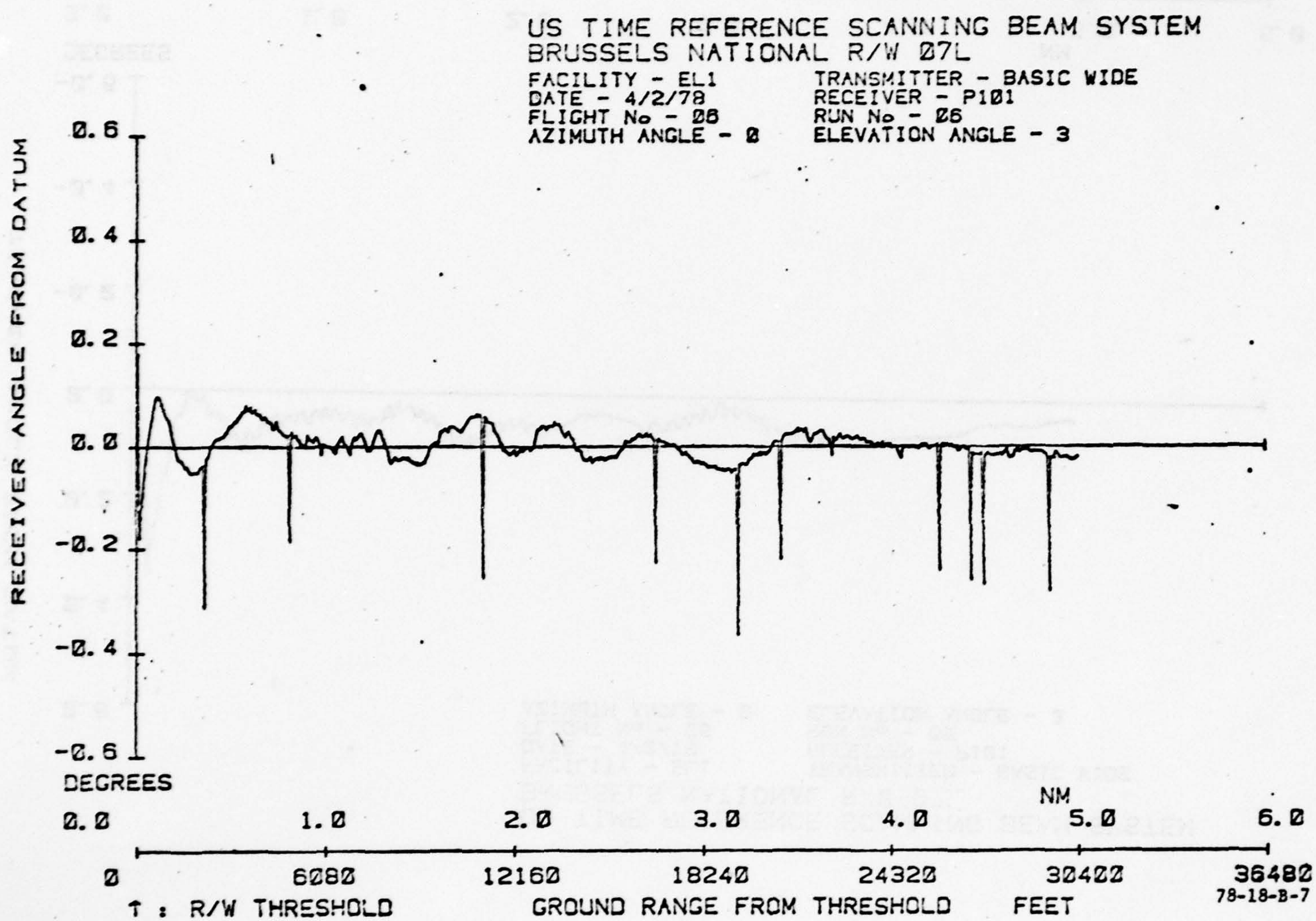

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø6
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø4
ELEVATION ANGLE - 2
TRACKER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
NM
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
304ØØ
3648Ø
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-14

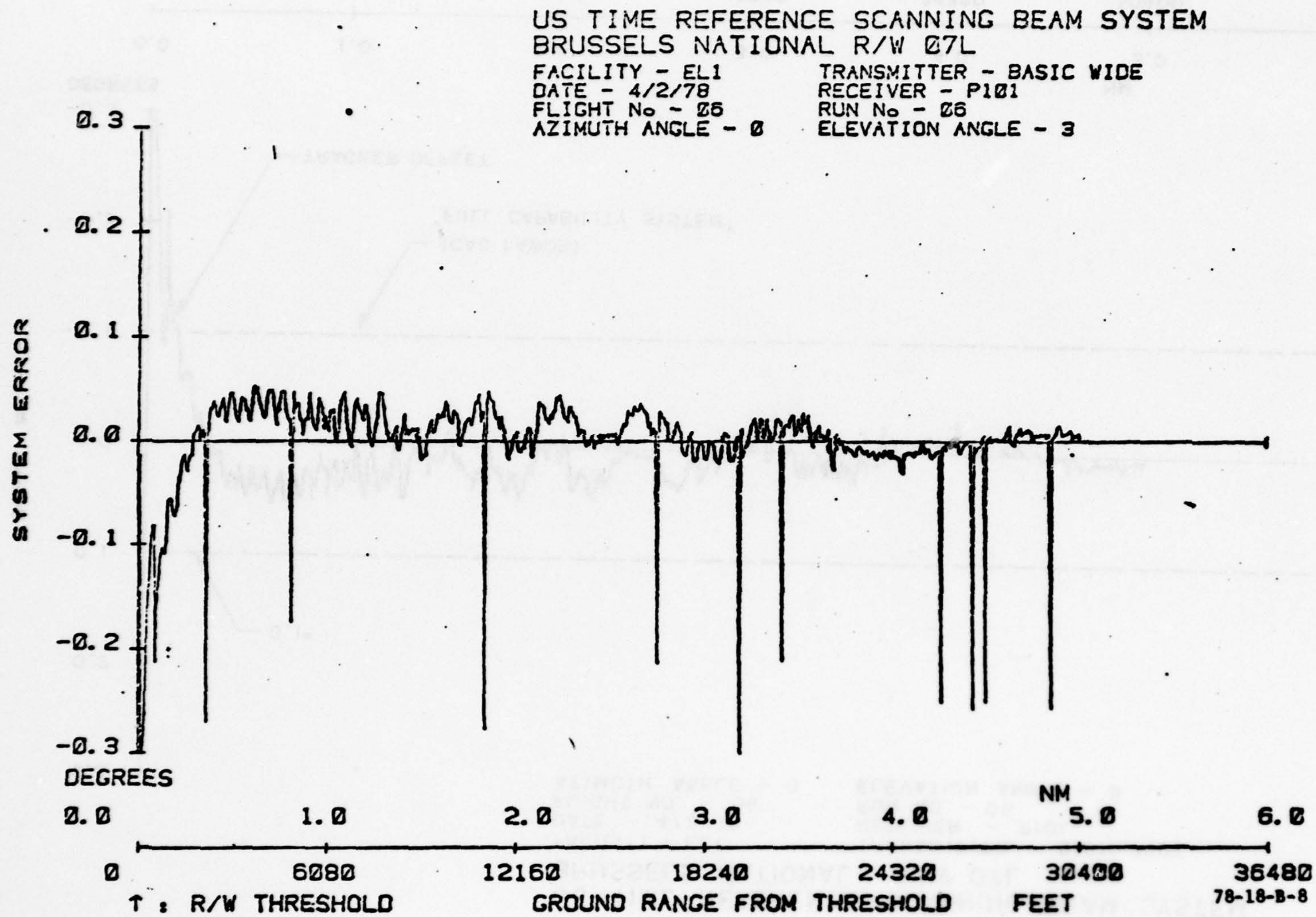

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - P101
RUN No - 04
ELEVATION ANGLE - 2
RECEIVER ANGLE FROM DATUM
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
6080
12160
18240
24320
30400
36480
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-15

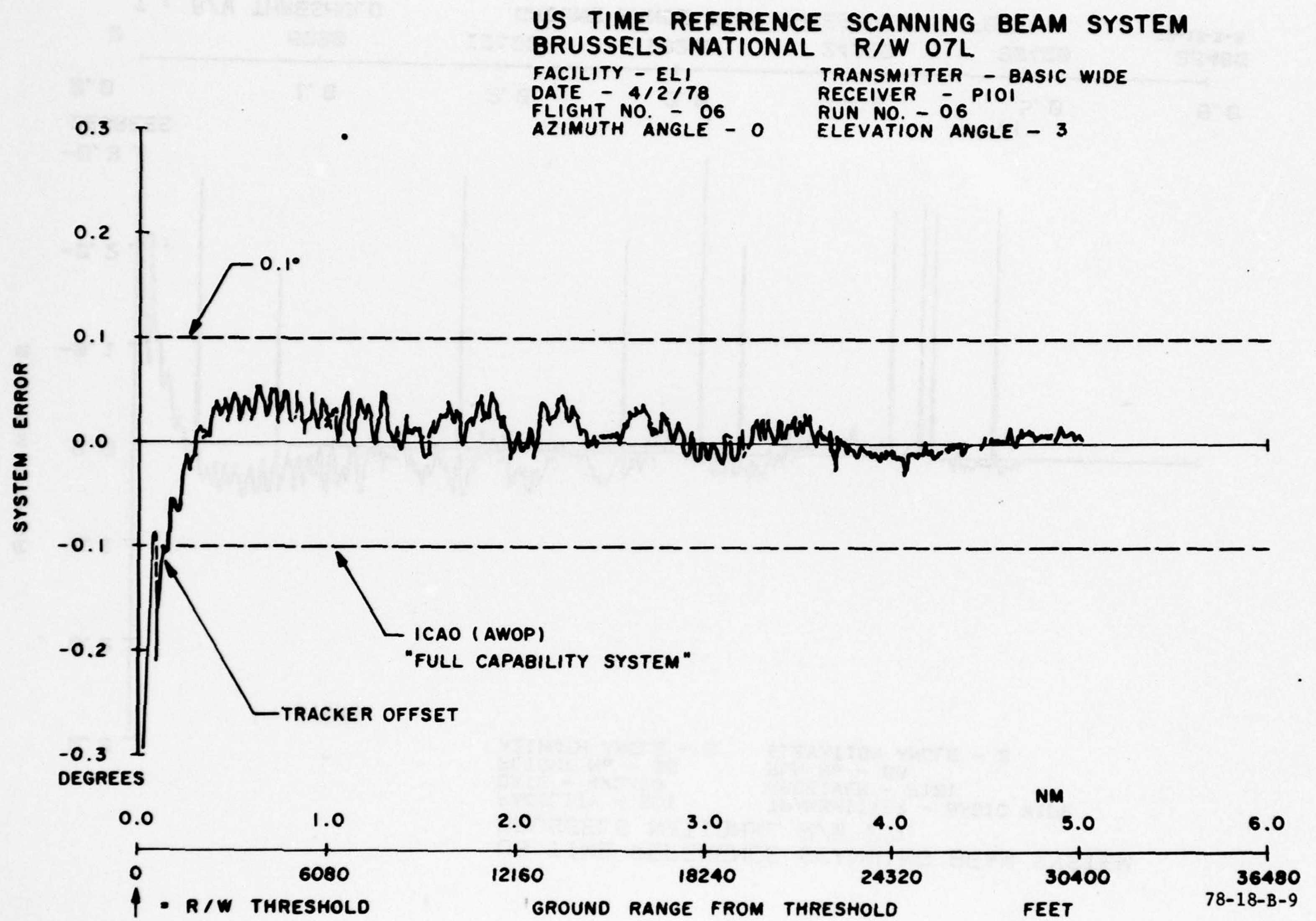

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - P101
RUN No - 04
ELEVATION ANGLE - 2
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
6080
12160
18240
24320
30400
36480
℄: R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-16

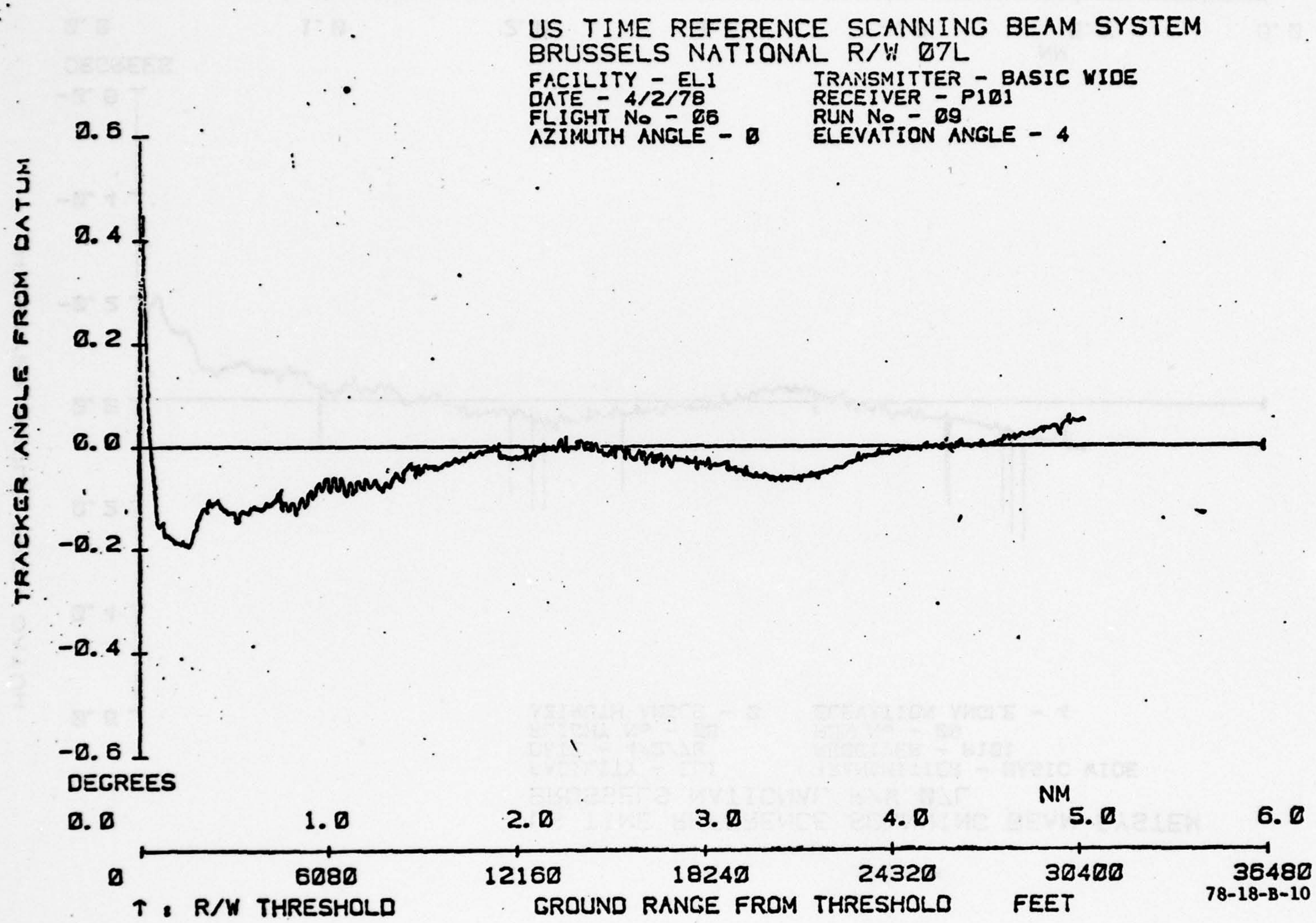

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - ELL
DATE - 4/2/78
FLIGHT NO. - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - P101
RUN NO. - 04
ELEVATION ANGLE - 2
SYSTEM ERROR
DEGREES
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0.1°
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
TRACKER OFFSET
NM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
6080
12160
18240
24320
30400
36480
↑ = R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-17

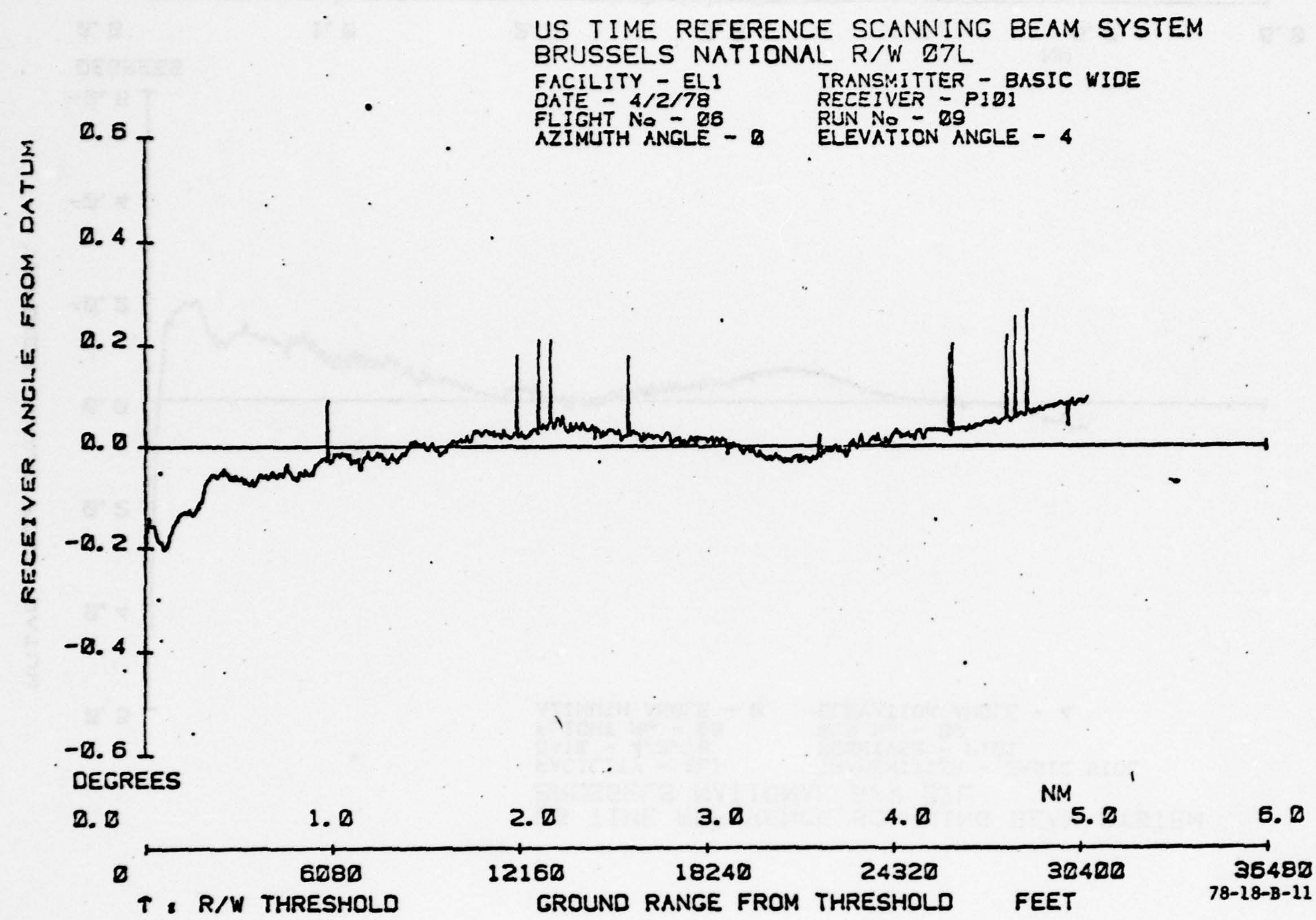

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø6
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø5
ELEVATION ANGLE - 3
TRACKER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
NM
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
304ØØ
3648Ø
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-6

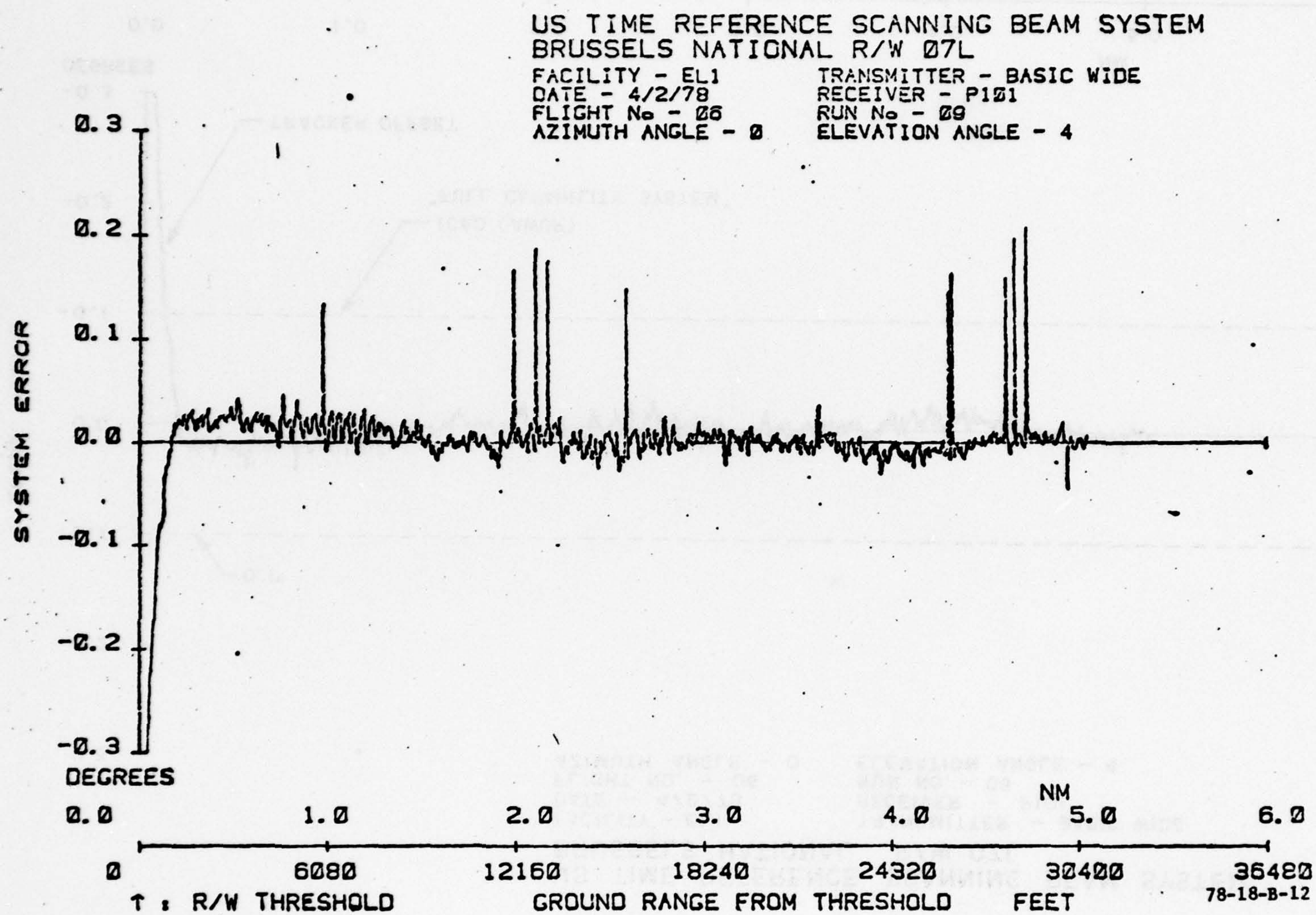

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø8
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø6
ELEVATION ANGLE - 3
RECEIVER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
NM
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
3Ø4ØØ
3648Ø
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET
78-18-B-7

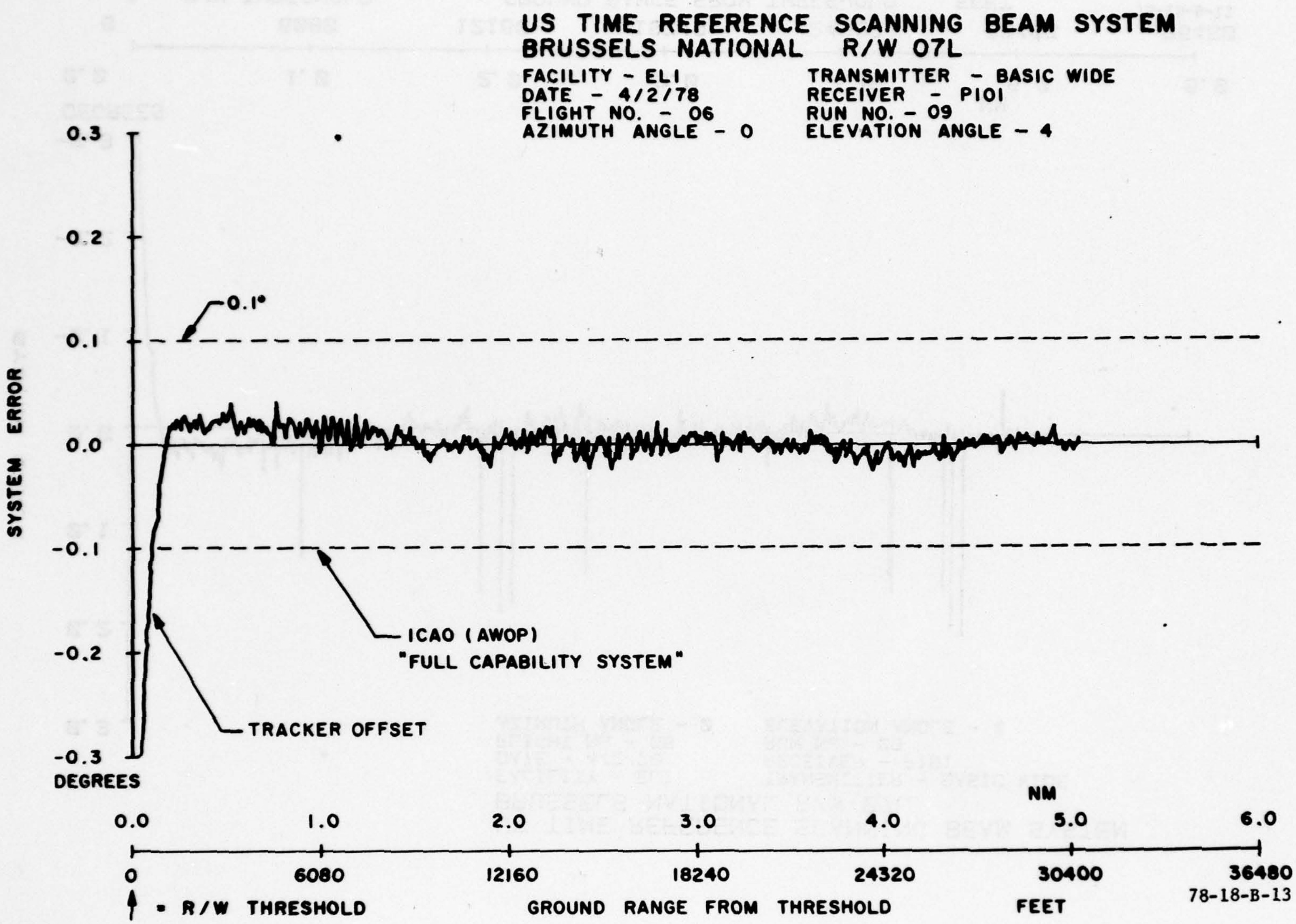

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø5
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø6
ELEVATION ANGLE - 3
SYSTEM ERROR
Ø.3
Ø.2
Ø.1
Ø.Ø
-Ø.1
-Ø.2
-Ø.3
DEGREES
NM
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
3Ø4ØØ
3648Ø
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-8

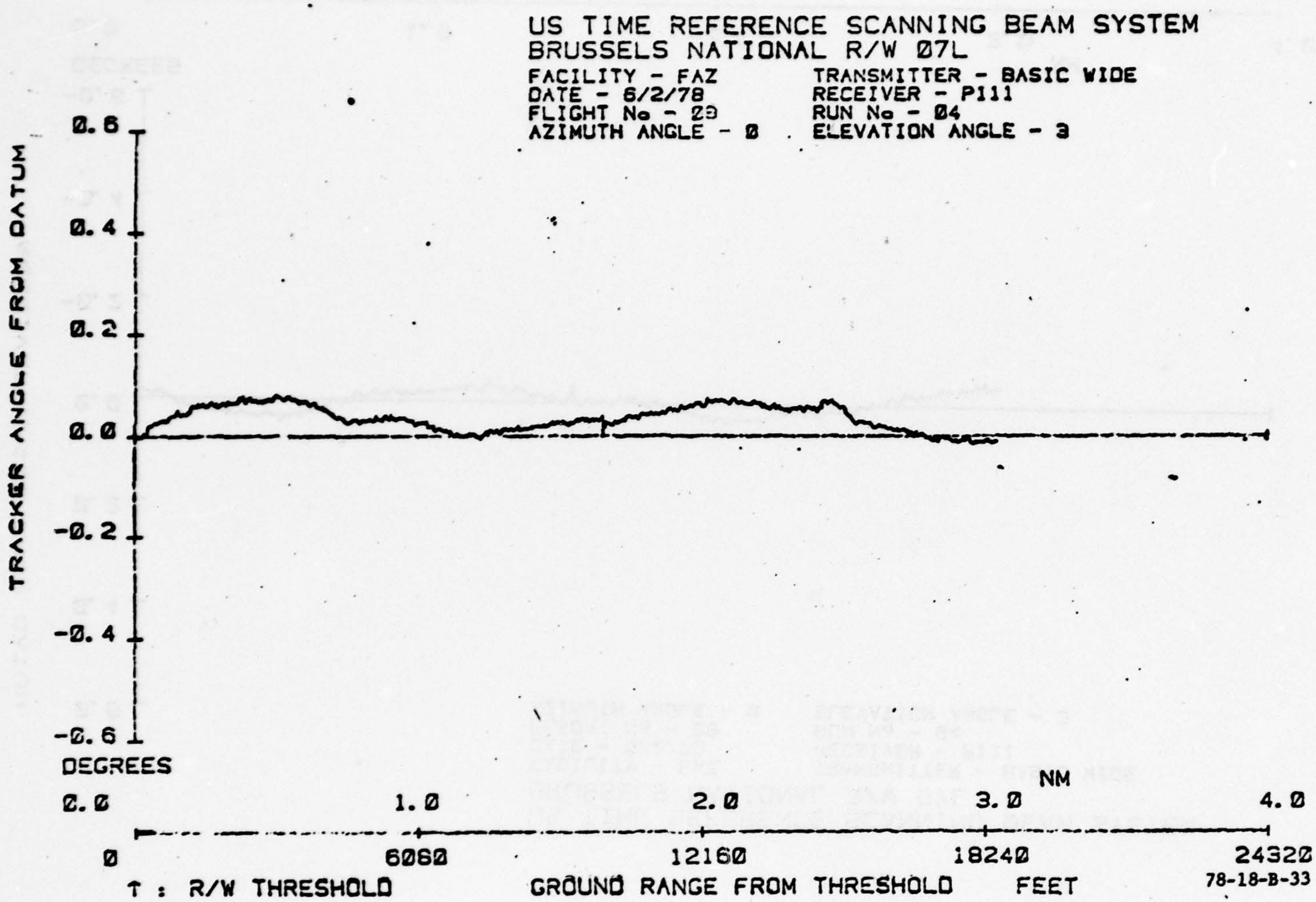

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - ELI
DATE - 4/2/78
FLIGHT NO. - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - PI01
RUN NO. - 06
ELEVATION ANGLE - 3
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
0.1°
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
TRACKER OFFSET
NM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
6080
12160
18240
24320
30400
36480
↑ = R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-9

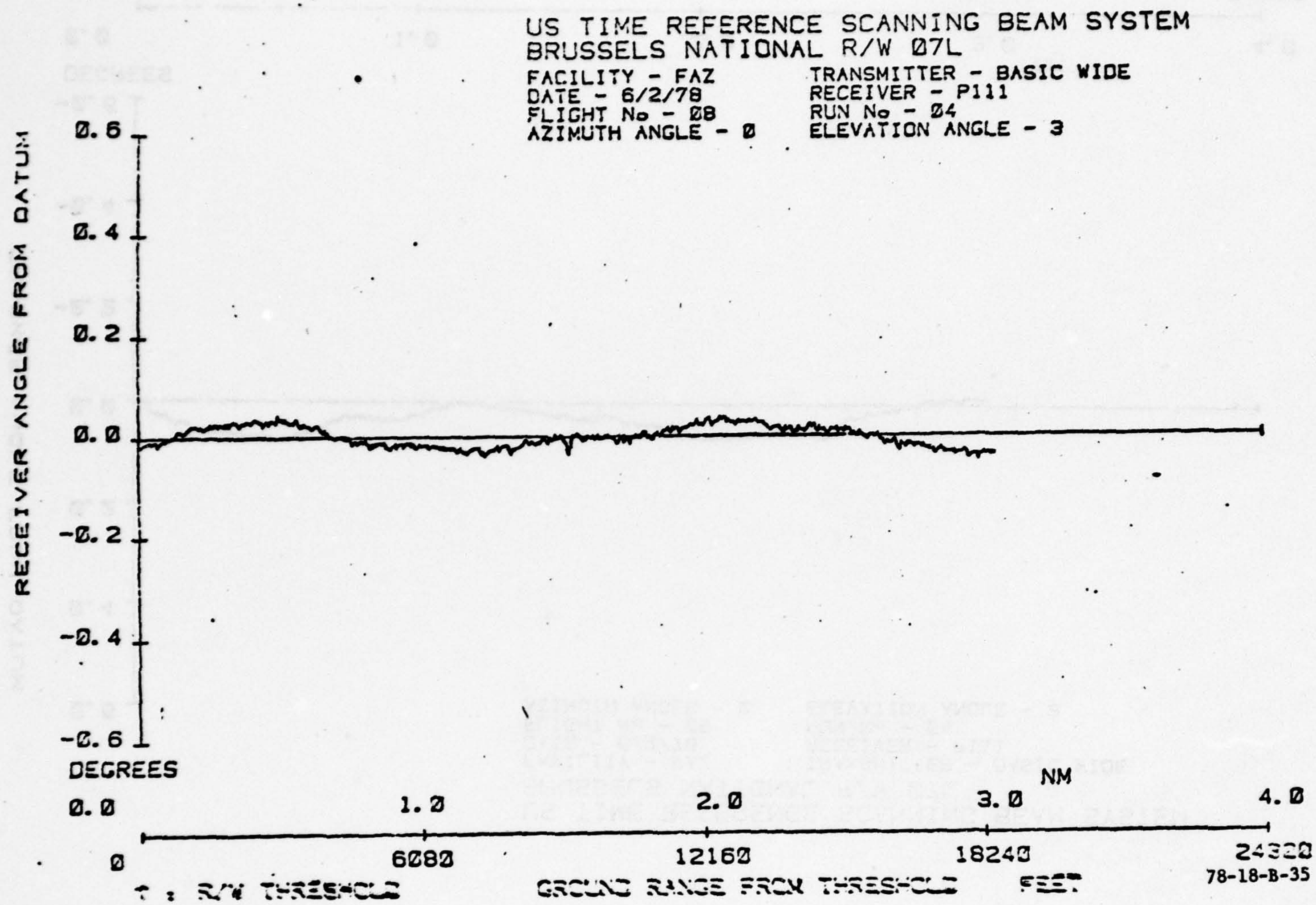

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø6
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø9
ELEVATION ANGLE - 4
TRACKER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
NM
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
304ØØ
3648Ø
FEET
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
78-18-B-10


US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - Ø8
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P1Ø1
RUN No - Ø9
ELEVATION ANGLE - 4
RECEIVER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
NM
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
5.Ø
6.Ø
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
304ØØ
3648Ø
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-11


US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - EL1
DATE - 4/2/78
FLIGHT No - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - P101
RUN No - 09
ELEVATION ANGLE - 4
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
0.0
1.0
2.0
3.0
4.0
5.0
6.0
NM
0
6080
12160
18240
24320
30400
36480
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-12


US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - ELI
DATE - 4/2/78
FLIGHT NO. - 06
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - P101
RUN NO. - 09
ELEVATION ANGLE - 4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
SYSTEM ERROR
0.1°
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
TRACKER OFFSET
NM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
6080
12160
18240
24320
30400
36480
= R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-13

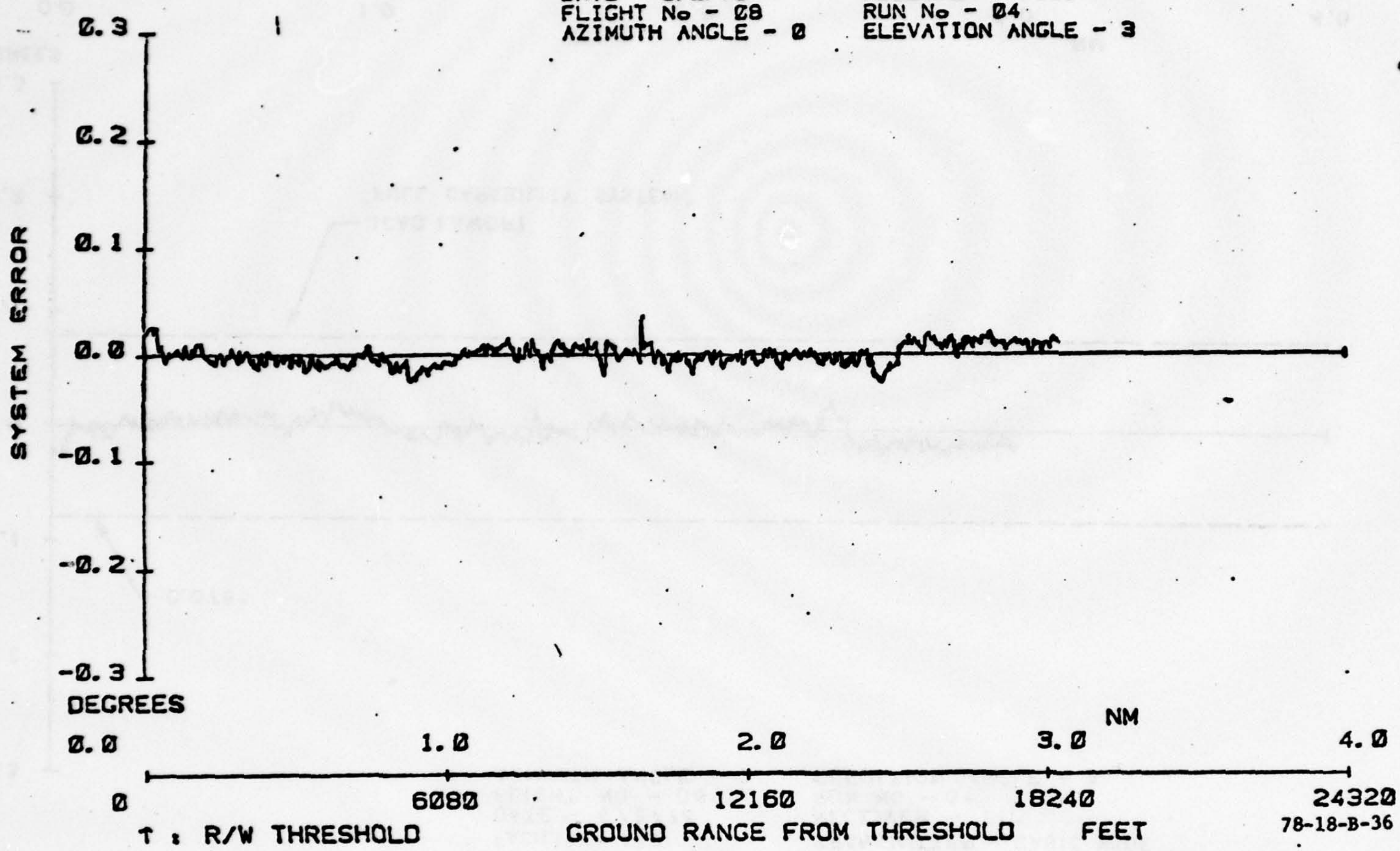

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - 23
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - Ø4
ELEVATION ANGLE - 3
TRACKER ANGLE FROM DATUM
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
DEGREES
0.0
1.0
2.0
3.0
4.0
NM
0
6080
12160
18240
24320
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET
78-18-B-33

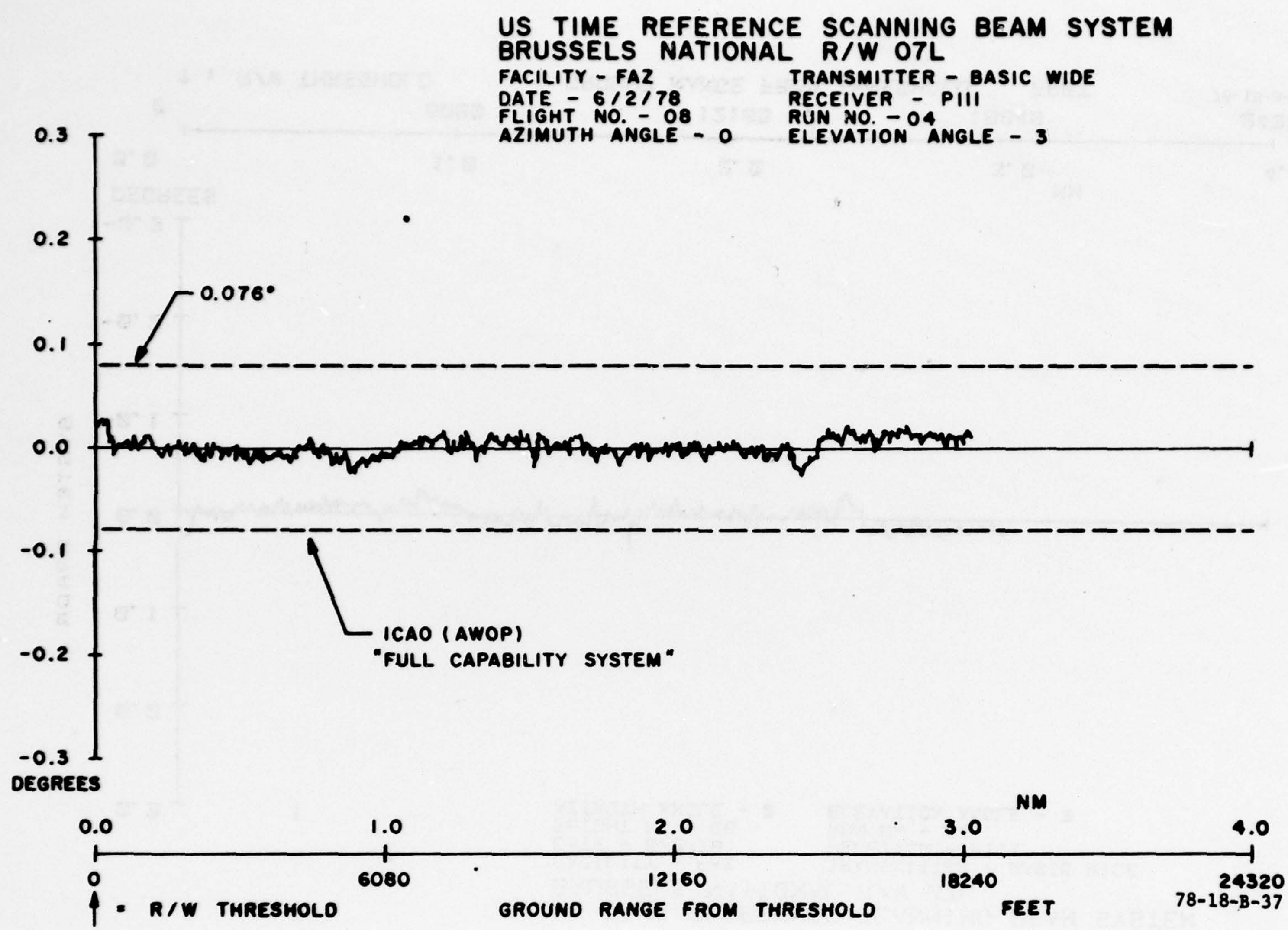

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - Ø8
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - Ø4
ELEVATION ANGLE - 3
RECEIVER ANGLE FROM DATUM
Ø.6
Ø.4
Ø.2
Ø.Ø
-Ø.2
-Ø.4
-Ø.6
DEGREES
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
NM
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET
78-18-B-35

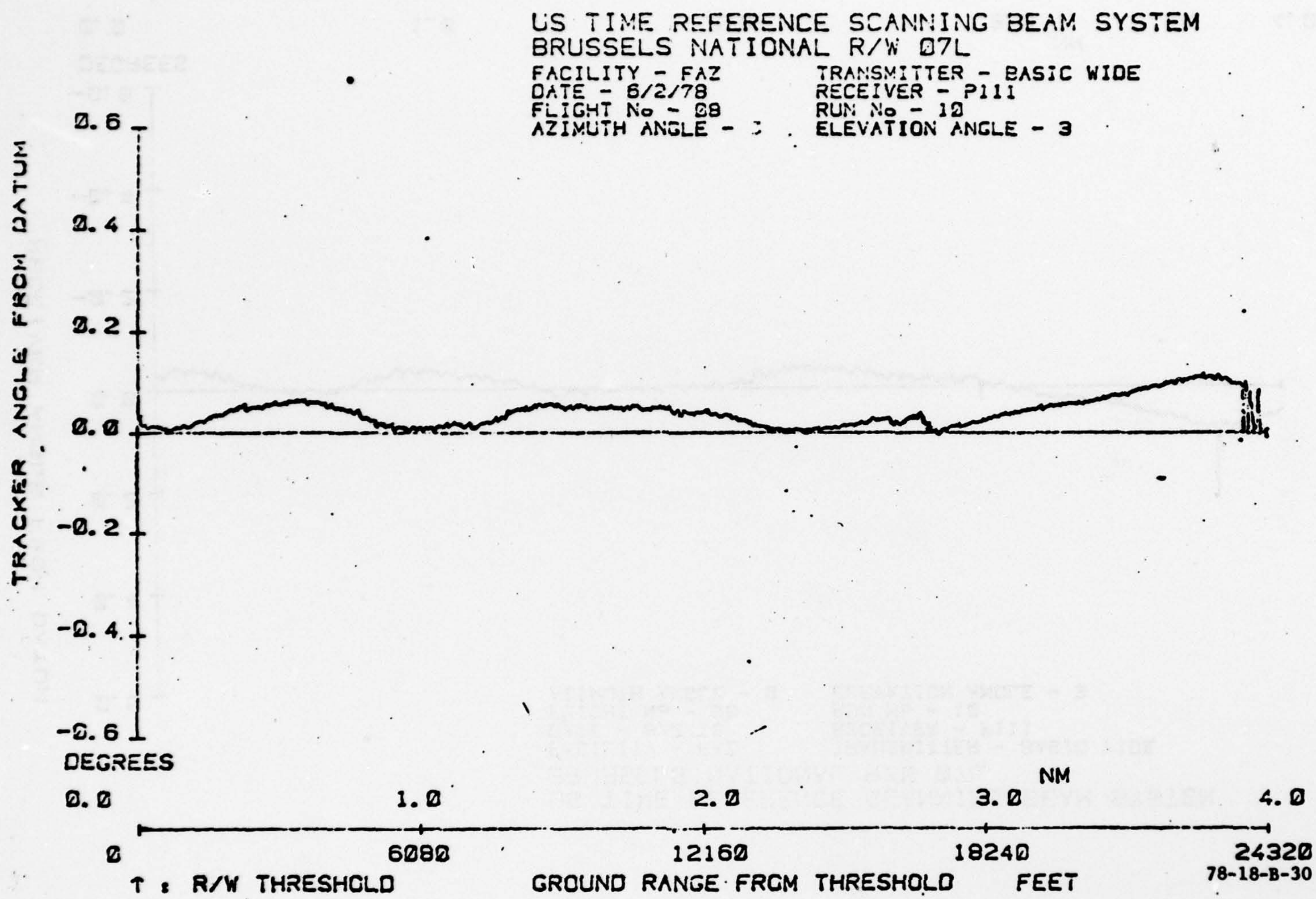
US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L

FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - 08
AZIMUTH ANGLE - 0

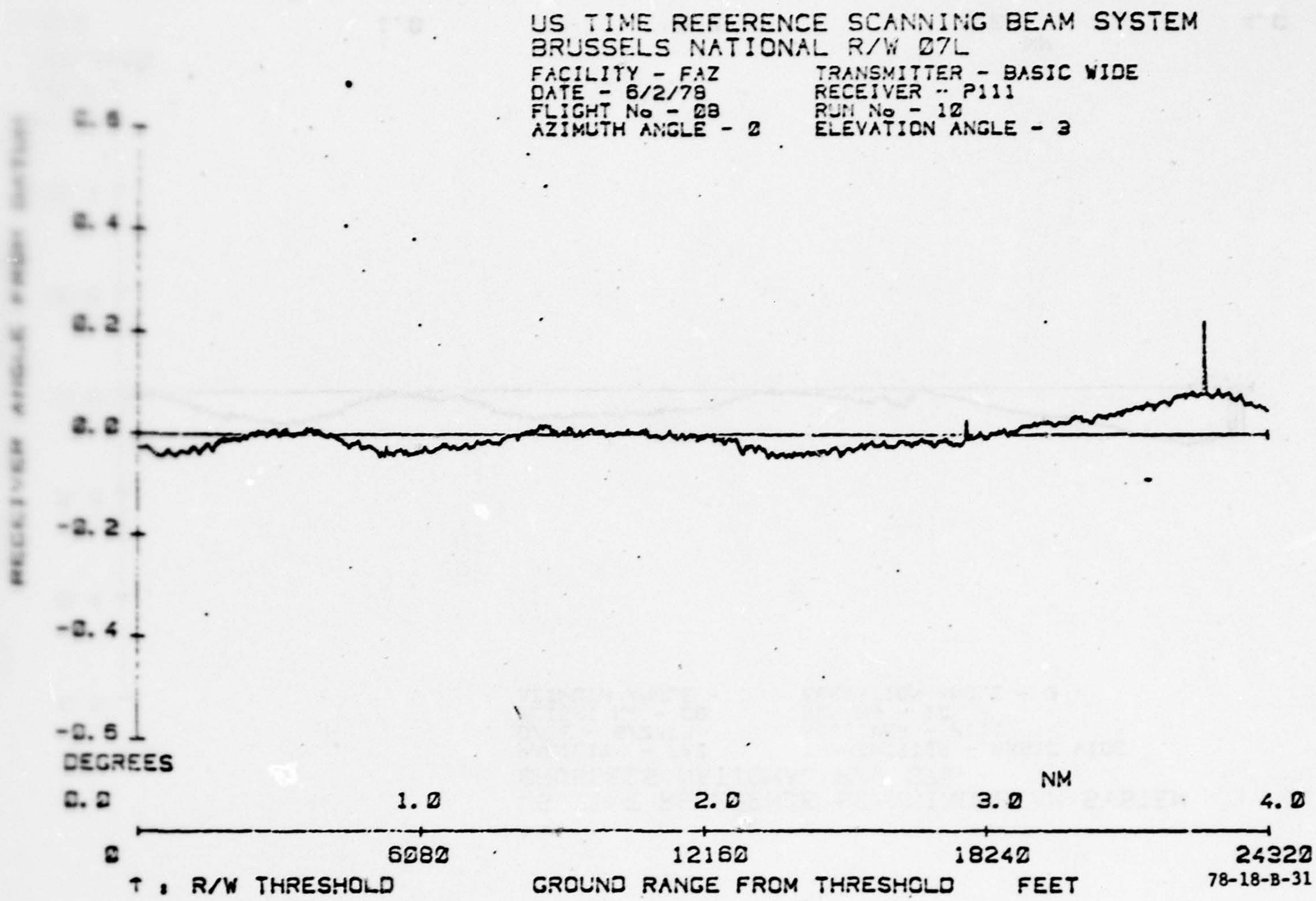
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - 04
ELEVATION ANGLE - 3

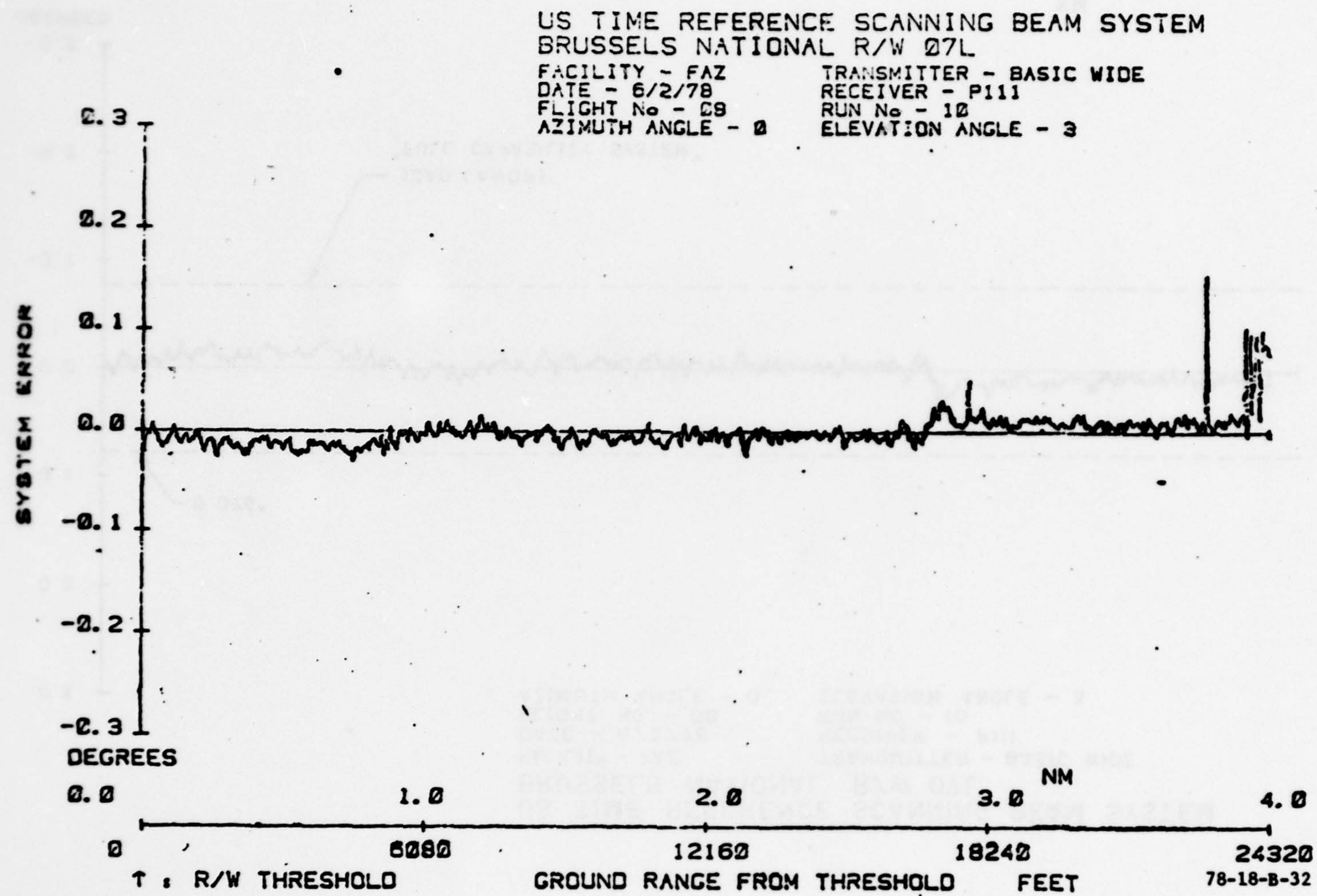



US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT NO. - 08
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC WIDE
RECEIVER - PIII
RUN NO. - 04
ELEVATION ANGLE - 3
0.076°
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
0
6080
12160
18240
24320
FEET
↑ = R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
78-18-B-37



US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - 08
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - 10
ELEVATION ANGLE - 3
TRACKER ANGLE FROM DATUM
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
0
6080
12160
18240
24320
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-30

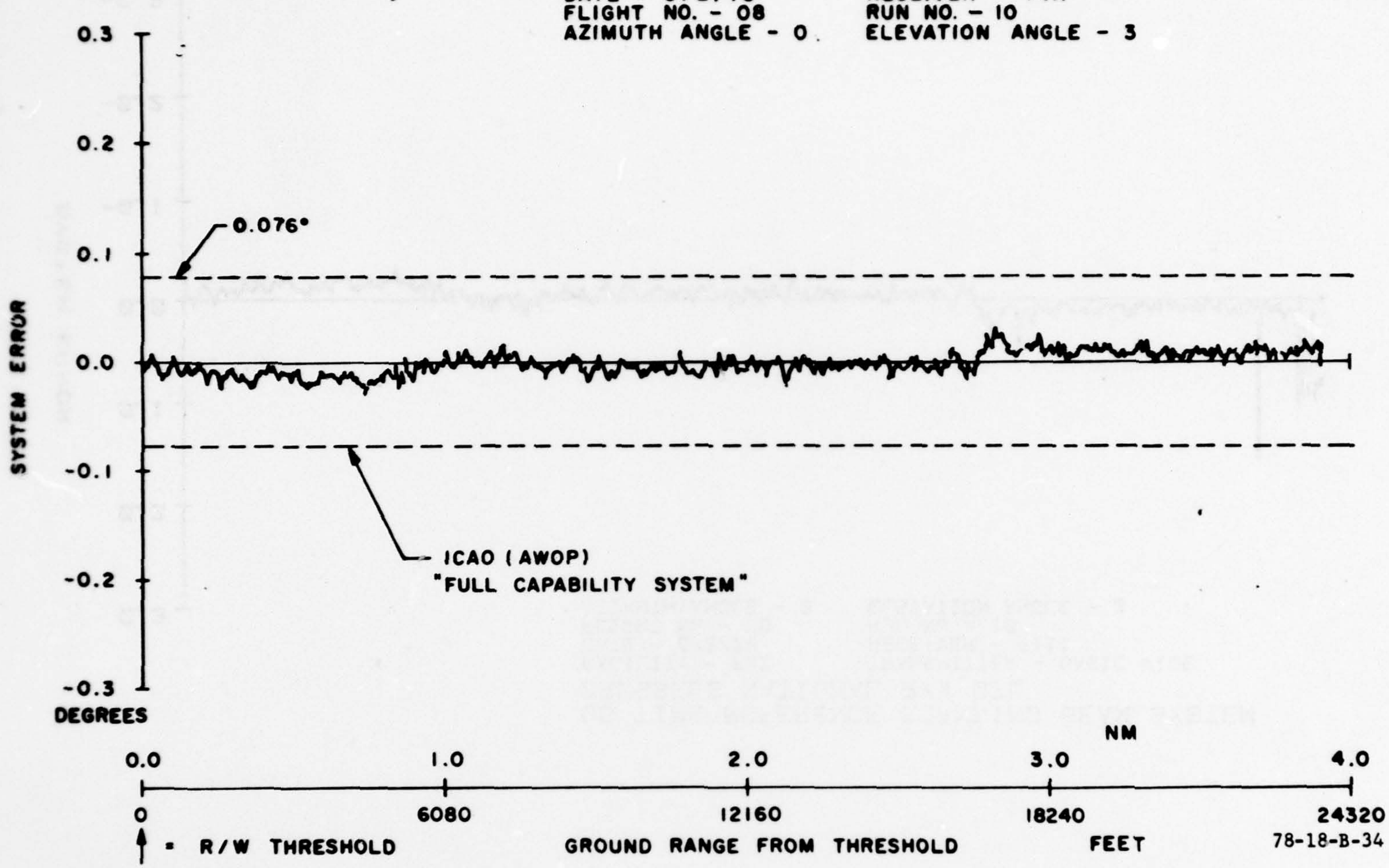

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - Ø8
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - 1Ø
ELEVATION ANGLE - 3
RECEIVER ANGLE FROM DATUM
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
DEGREES
0.0
1.Ø
2.Ø
3.Ø
4.Ø
NM
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET
78-18-B-31


US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W Ø7L
FACILITY - FAZ
DATE - 6/2/78
FLIGHT No - C8
AZIMUTH ANGLE - Ø
TRANSMITTER - BASIC WIDE
RECEIVER - P111
RUN No - 1Ø
ELEVATION ANGLE - 3
SYSTEM ERROR
Ø.3
Ø.2
Ø.1
Ø.Ø
-Ø.1
-Ø.2
-Ø.3
DEGREES
Ø.Ø
1.Ø
2.Ø
3.Ø
4.Ø
NM
Ø
6Ø8Ø
1216Ø
1824Ø
2432Ø
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-18-B-32

US TIME REFERENCE SCANNING BEAM SYSTEM
BRUSSELS NATIONAL R/W 07L

FACILITY - FAZ
DATE - 6/2/78
FLIGHT NO. - 08
AZIMUTH ANGLE - 0

TRANSMITTER - BASIC WIDE
RECEIVER - PIII
RUN NO. - 10
ELEVATION ANGLE - 3



78-18-B-34