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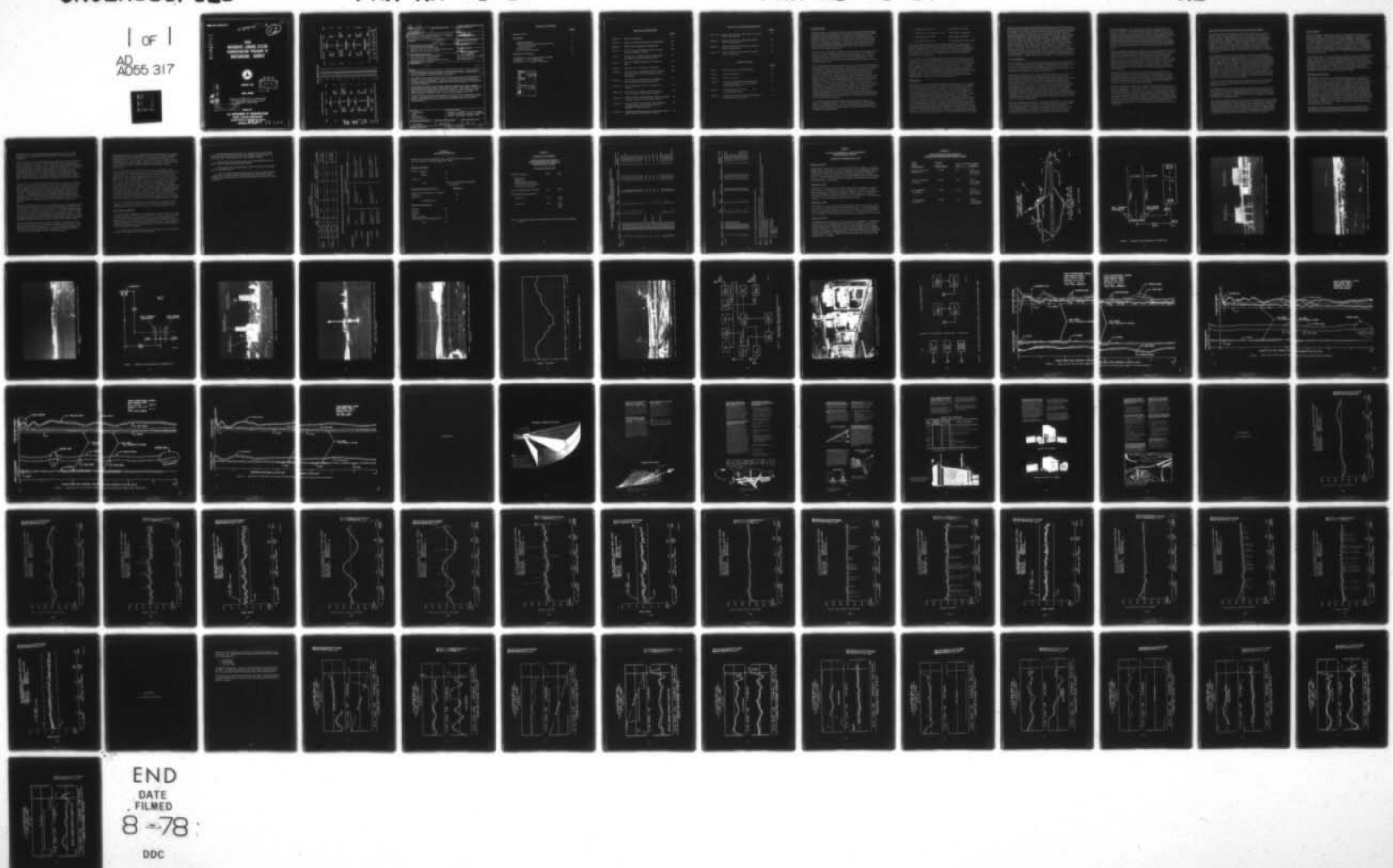

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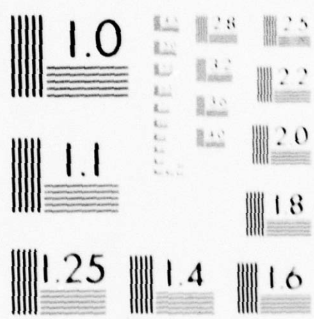
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Report No. FAA-RD-78-17

TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT KRISTIANSAND, NORWAY

JANUARY 1978

FINAL REPORT

Prepared for

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

METRIC CONVERSION FACTORS

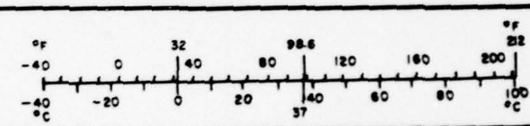
Approximate Conversions to Metric Measures

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



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16. Abstract

The demonstration at Kjevik Airport, Kristiansand, Norway, was the fifth in a series of operational demonstrations of several TRSB system configurations at selected airports in the United States and abroad.

Two TRSB system configurations, Basic Narrow Aperture and Small Community Systems, were installed to service the non-instrument Runway 22 which has a normal 4° approach glidepath. Approach to this runway is along a valley with surrounding terrain obstructions that subtend elevation angles to 2.8° within 20° of runway centerline.

Operational demonstrations and data acquisition flights were made utilizing an FAA Boeing 727 test aircraft. Flight profiles included approaches, radials, and partial orbits perpendicular to the runway centerline. Some flight tests were also made by Norwegian and British Civil Aviation Authority personnel using TRSB equipment installed in their respective flight inspection aircraft.

Results of the operational demonstrations indicated that the performance of both system configurations was well within their respective U.S. Phase III program design requirements and also met ICAO (AWOP) "full capability system" requirements.

17. Key Words
Kristiansand
TRSB
Basic Narrow
Small Community

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing have 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 eventually 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 demonstrations at operational airports, the FAA has developed a program to conduct operational demonstrations of several TRSB MLS hardware configurations at selected airports in the United States and abroad. (Hereafter 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 Category 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 its applicability to their particular requirements.

The TRSB operational demonstration and data acquisition flights of January 23 through January 26, 1978, at Kjevik Airport, Kristiansand, Norway, was the fifth effort in a series of operational demonstrations at domestic and foreign operational airports. Previous operational demonstrations were conducted at:

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

The TRSB demonstrations at Kjevik Airport afforded civil and military aviation officials and technical experts from Norway and other European countries, NATO, and the General Aviation Community, the opportunity to observe and participate in flight demonstrations, technical briefings and discussions, and to inspect the TRSB ground equipment configurations installed on the airport sites.

Kjevik Airport, owned and operated by the Norwegian Directorate of Civil Aviation, is situated in Southern Norway near the city of Kristiansand. It supports general aviation, domestic, and international commercial airline service within Scandinavia and to other European countries. The airport has a single runway (04/22), 1900 meters (6234 feet) long. The existing Category I Instrument Landing System permits precision approaches to Runway 04. Runway 22, utilized for the installation of the two TRSB system configurations, is a non-instrument runway with a 4-degree elevation approach path. Figure 1 shows the airport plan view and location of the TRSB subsystem elements with respect to Runway 22.

DISCUSSION

The TRSB system configurations installed at Kjevik Airport were manufactured by the Bendix Corporation's Communications Division in accordance with FAA specifications (refer to Table 1). The system configurations were: (1) The Basic Narrow System with system accuracy designed to support operations to Category II on runways to 2438 meters (8000 feet), and (2) the Small Community System, representative of a simple, economical system configuration, designed to provide better than Category I service on runways to 1524 meters (5000 feet). The Basic Narrow System, which has antenna beamwidths of 2° for the azimuth antenna and 1.5° for the elevation antenna, provides azimuth proportional guidance to plus and minus 40 degrees about runway centerline with a range of better than 20 nautical miles under heavy precipitation conditions, and elevation coverage of selectable glide slope angles from 2 degrees to 15 degrees over the same distance. An auxiliary data channel is included for transmission of facility status information to approaching aircraft. An independent precision L-band distance measuring equipment (DME) provides range data with at least 30-meter (100-foot) 2 sigma system accuracy when used with a precision airborne interrogator. The Small Community System, which has antenna beamwidths of 3° for the azimuth antenna and 2° for the elevation antenna, provides proportional guidance to plus and minus 10 degrees about the runway centerline with a minimum range of 20 nautical miles. Fly-left/fly-right guidance is provided between the plus and minus 10-degree azimuth proportional sector out to plus and minus 40 degrees of runway centerline to bring the approaching aircraft into the precision guidance sector. Elevation guidance provides selectable glide slope angles from 2 degrees to 15 degrees. As with the TRSB Basic Narrow System, capability for auxiliary data transmission is included. Precision L-band DME is not necessarily a component of the TRSB Small Community System, but was available for the operational demonstrations at Kjevik Airport since the two system configurations were installed together. General information on TRSB is contained in Appendix A.

System Installation

An FAA advance team visited Kjevik International Airport on December 8, 1977, to inspect the selected azimuth and elevation sites previously utilized by the U.K. in flight trials of the Doppler MLS System, and to make necessary arrangements for TRSB installations and required ground service support for the scheduled operational demonstrations.

On January 15, 1978, the FAA Boeing 727 test aircraft, N-40, arrived at Kjevik Airport transporting the TRSB Small Community System and supporting FAA personnel. On the following day, this equipment was transported to the azimuth and elevation sites, assembled, installed, and mechanically aligned. On January 17, 1978, the Basic Narrow System configuration arrived on a U.S. Air Force C-141 cargo transport aircraft, was transported to its respective azimuth and elevation sites, installed, and aligned on the following day. By January 20, 1978, both the Basic Narrow and Small Community Systems were operational. It should be noted that during this 5-day period, alternate heavy rain and snow conditions prevailed. Due to weather conditions, flight check of the two TRSB system configurations was delayed until early on the morning of January 24, prior to the first demonstration flight.

The two azimuth subsystems were collocated and offset 85.5 meters (280.5 feet) north of Runway 22 centerline at a position 80.9 meters (265.5 feet) beyond the stop end of the runway. It should be noted that both the U.S. TRSB and the U.K. Doppler azimuth subsystems, the latter tested during September/October 1977, were offset from runway centerline because of insufficient area behind the runway stop end for a normal azimuth installation. The stop end of the runway is approximately 50 meters (164 feet) from Kristiansand Fiord with a drop to the water level of similar distance. Due to the location north of runway centerline, both TRSB azimuth subsystem antennas were mechanically aligned 0.5 degrees offset from a normal antenna mounting position to provide the proper radiation pattern alignment for a centerline approach path to the runway. Because of prevaling and potentially increasing snow levels, the azimuth antennas were set on their vertical mounting fixtures to the full adjustable height, providing approximately 1.2 meters (4 feet) clearance from the ground.

Figure 2 provides information on both Basic Narrow and Small Community azimuth subsystem installations near the stop end of Runway 22. Figure 3 depicts the installation and site, while Figure 4 shows the equipment shelter for the Basic Narrow azimuth subsystem electronics, located approximately 33.5 meters (110 feet) north of the antenna enclosure. The precision L-band DME was also housed within this shelter and its antenna attached to the outside of the building. Small Community azimuth subsystem electronics are located within its antenna enclosure. Figure 5 shows an overall view of the azimuth site with the Kristiansand Fiord in the background.

The Basic Narrow and Small Community elevation subsystems were collocated and offset 90 meters (295 feet) south of Runway 22 centerline at a position 210 meters (689 feet) back from runway threshold. Both subsystem antenna enclosures were mounted at their normal height from ground level since their mounting fixtures provide approximately 0.76 meters (2.5 feet) clearance from ground level.

Detailed information on siting of the TRSB elevation antenna structure with respect to Runway 22 is provided in Figure 6. Figure 7 shows the elevation site installations. An overall view of the site is presented in Figure 8, with the Basic Narrow far field monitor antenna in the foreground. Figure 9 is a view of the area in front of Runway 22 showing the natural terrain obstructions along the centerline approach to the runway as observed from the elevation site at a position approximately parallel to runway centerline. Figure 10 presents details of the horizon profile as measured from a position between the Basic Narrow and Small Community elevation antenna enclosures.

TRSB Operational Demonstrations and Data Acquisition Flights

The TRSB operational demonstration briefings conducted on January 23 and 24, 1978, were well attended. There were 54 persons from six countries who formally registered and several others who attended but did not register. Approximately one-half of the attendees participated in the demonstration flights. No demonstration flights were flown on January 23, due to adverse weather conditions, but two were flown on January 24. Six observers from the Norwegian Telecommunications Administration, flew on a data acquisition flight on January 26. Table 2 presents a summary and Table 3 the schedule of events for the demonstration program.

An FAA Boeing 727 test aircraft, shown in Figure 11, was utilized for demonstration and data acquisition flights. The demonstration flights on January 24, consisted of approaches to Runway 22 at 4-degree glide slope angle. Approaches were initiated 10 nautical miles from runway threshold and terminated with a low approach and continued flight over the length of the runway at a constant altitude. On the first demonstration flight, three approaches were made on a course 1-degree left of runway centerline. Two approaches were made on the second flight, both on a course of 1-degree left of runway centerline; however, due to inclement weather, the aircraft descended only to 3,000 feet before leveling off for the continuation of the run. Both Basic Narrow and Small Community System configurations were demonstrated on each flight.

A total of 36 data acquisition runs were flown with the B-727 aircraft on January 25 and 26. Flight details and TRSB configurations flown are presented in Table 4.

Some flight tests were also conducted by Norwegian and U.K. Civil Aviation Authority personnel utilizing TRSB avionics equipment installed in their respective aircraft. Sample data from the U.K. tests are included in Appendix B. The U.K. data collection activity on TRSB was in accordance with a bilateral agreement.

The prevailing weather during operational demonstration days was generally bad, and had significant impact on the number of independent observers who could witness performance of the TRSB system configurations. Improved weather conditions on the 2 days devoted to data acquisition flights enabled collection of performance data on the Basic Narrow System configuration. Minimal performance data was acquired on the Small Community System. A synopsis of each days weather conditions is contained in Table 5.

Airborne System

The B-727 airborne TRSB system consisted of dual angle receivers, course direction indicators, and precision DME interrogators. Instrumentation used for data acquisition consisted of a data multiplexer, digital data recorder, analog video recorder, *strip chart recorder*, time code generator, VHF telemetry receiver/demodulator, and a modified UHF glide slope receiver. The latter two listed items were required to receive the optical tracker angle data transmitted from the TRSB ground sites. The interrelation of the airborne TRSB system and instrumentation with the B-727 flight control system is shown in Figure 12. The data instrumentation system is depicted in Figure 13.

A *wide angle, plus and minus* 85 degrees, antenna mounted in the nose section of the aircraft under the weather radar antenna, and an omni-directional antenna mounted on the aircraft fuselage just above the center of the cockpit windshield (Figure 11), were available so that either could be alternately switched to either of the TRSB angle receivers installed in the test aircraft. It should be noted, however, that for all of the data presented in this document, except Appendix C, only the angle data from the TRSB receiver connected to the omni-directional antenna was utilized.

Performance Assessment

Ground based tracking for the TRSB demonstrations was provided by two different types of optical trackers used interchangeably at azimuth and elevation sites as requirements dictated. Simultaneous tracking of azimuth and elevation was generally provided for all flights. One of the trackers was a manually operated radio-telemetry theodolite (RTT), used to transmit azimuth or elevation angle position (depending upon its siting for the flight) to the aircraft via a transmitter operating on an unused UHF glide slope channel. The second tracking system (used to track elevation when the RTT tracked azimuth or azimuth when the RTT tracked elevation) was an optical electronic tracker manufactured by British Aircraft Corporation of Australia, designed to automatically or manually track a light source on the aircraft. Angular position data was telemetered back to the aircraft on an available VHF frequency. Figure 14 depicts the TRSB ground equipment and tracking systems.

During data acquisition flights, the portable tracker equipment were positioned at the respective TRSB azimuth and elevation sites as follows: Azimuth site on the antenna(s) radiation centerline directly below the antenna enclosure of the TRSB system configuration under test; at the elevation site, in alignment with, and between the respective antenna enclosures.

In the aircraft, the received analog tracker angle data, azimuth and elevation, was subtracted from the TRSB azimuth and elevation angle data to provide a measure of system error. In each case (azimuth and elevation), the angle difference as well as tracker angle and TRSB angle were recorded on light sensitive strip chart recorder paper on an analog recorder. Additionally, airborne received angle data from the optical electronic tracker in digital format was recorded together with TRSB digital angle data and time code data on a digital recorder to facilitate greater flexibility in data processing and analysis at NAFEC as required (see Appendix C).

Figures 15, 16, 17, and 18 are data from airborne strip chart recordings for four runs conducted on January 25, 1978. Each of these figures contains a reproduced trace of aircraft tracked angle, TRSB receiver angle, and the difference between the two (error), for both the elevation and azimuth. For data presentation, small alignment bias errors have been removed. The longitudinal axis of these plots represents range from Runway 22 threshold determined by the TRSB precision DME located at the azimuth site. ICAO error limit boundaries (refer to Table 6) for "full capability system" configuration have been included on the figures as shown.

Referring to Figure 15 which is a 2-degree left azimuth radial and 3-degree elevation approach angle on the Small Community System, and Figure 16, which depicts a 2-degree left azimuth radial at an elevation approach angle of 2.5 degrees on the Basic Narrow System, it is apparent that both TRSB systems are within the ICAO (AWOP) error limits of ± 0.1 degree in elevation and ± 0.076 degree in azimuth for the "full capability system." It is to be noted that this is consistent with data obtained under instrumented range conditions during enginerring acceptance testing of the systems earlier.

Data for the Basic Narrow System shown in Figure 17 represents a zero-degree azimuth approach on a 4.0-degree elevation approach angle, while that depicted in Figure 18 represents a 1-degree left azimuth radial on a 4.0-degree elevation approach angle. Here again the TRSB system is within ICAO error limits for the "full capability system."

Although data acquired on the TRSB Small Community System was limited, its performance was demonstrated to be within the U.S. Phase III program design requirements as well as the more stringent ICAO (AWOP) "full capability system" requirements. Further, a review of the data acquired on the TRSB Basic Narrow System shows it to be within the Phase III design requirements as well as the ICAO (AWOP) "full capability system" requirements.

The U.K. flew against the Basic Narrow System using TRSB airborne receiver processors provided by the U.S. The U.K. designed the necessary interface unit to record the TRSB data in their HS-748 twin engine turbo prop test aircraft. Sample data plots obtained by the U.K. are shown in Appendix B. Three separate plots, tracker, receiver output, and differential or error plots are presented by the U.K. for each data run. The U.K. data contains "extraneous spikes" which are not normally seen in TRSB data and are believed to be caused by the recorder interface equipment aboard the U.K. aircraft. Appendix C contains sample plots of TRSB digital data recorded in the U.S. test aircraft at Kristiansand. These plots do not contain any "extraneous spikes." Therefore, for data presentation papers, an additional plot has been added for each run of U.K. recorded TRSB data (three U.K. plots plus one) with the "spikes" removed. In the review of the U.K. data, it should also be noted that oscillations are very evident in the tracker data and can be seen in the corresponding system error plots.

The U.K. error plots of TRSB data and the additional clean plots without "spikes" show that the performance of the TRSB Basic Narrow System configuration is within ICAO error limits for the "full capability system."

SUMMARY OF RESULTS

Two TRSB system configurations are discussed in this document; the Small Community System, which is representative of a simple, economical TRSB version, and the Basic Narrow System, an economical TRSB hardware design similar to the Small Community System, but with greater volumetric proportional guidance coverage and smaller beamwidths. In addition to the economical design feature, the information on these two system configurations presented herein indicates:

1. Performance of both TRSB system configurations was within ICAO (AWOP) "full capability system" requirements.

2. Sample data provided by the U.K. (Appendix B) on their TRSB flight tests at Kristiansand, indicates that the Basic Narrow System is within the ICAO error limits for the "full capability system."

3. Both TRSB system configurations were demonstrated to exceed their respective Phase III design requirements.

4. Both TRSB system configurations required minimal site preparation and installation time.

5. The successful operational performance of the two TRSB system configurations at Kjevik Airport demonstrated the capabilities of each system design for application at airports with difficult weather and terrain conditions.

TABLE 1.

TRSB ACCURACY, PHASE III SYSTEMS

			BIAS (DEG.)	PATH FOLLOWING NOISE (DEG.)	PATH FOLLOWING ERROR (DEG.)	CONTROL MOTION NOISE (DEG.)	REMARKS
Basic Narrow	AZ	SPEC	.19	.08	.2	.07	at 50' on 2.5° G/S
	EL	SPEC	.08	.09	.12	.05	
Small Community	AZ	SPEC	.29	.15	.33	.10	at 150' on 2.5° G/S
	EL	SPEC	.11	.12	.16	.10	

NOTES ON TRSB ALLOWABLE PFE DEGRADATIONS (PHASE III CONTRACTS)

	PFE Degradation W/Distance	W/Azimuth Angle	W/Elevation Angle
Basic Narrow			
Azimuth	None	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 20°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 20°
Small Community			
Azimuth	Linearly to 0.4° at 20 NM	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 15°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 15°

TABLE 2.
SUMMARY STATISTICS

TRSB operational demonstrations/data acquisition effort--Kristiansand, Norway, January 23 through January 26, 1978.

Registered Visitors

January 23	(Press)	5
	(TV)	1
	(Other)	31
January 24		17
	Total	54 (plus several others who failed to register)

Flight Demonstrations, B-727	Observers
January 23 (cancelled due to weather)	
January 24	20
January 26	6
Total Observers	26

Countries Represented

Norway	40
Sweden	6
Denmark	3
Spain	2
United Kingdom	1
United States (Embassy attachee)	2
Total	54

TABLE 3.

SCHEDULE OF EVENTS

UNITED STATES OF AMERICA
TRSB DEMONSTRATION PROGRAM
KRISTIANSAND, NORWAY

January 23 and 24, 1978

TRSB Presentation	0900	1300
Introduction TRSB Film TRSB System Hardware ICAO/AWOP MLS Program Questions and Answers		
Visit to TRSB Ground Facilities	1030	1300
TRSB Flight Demonstrations:		
January 23	1030	1330 1430
January 24	0900	1230 1330 1430

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

TABLE 4.

TRSB OPERATIONAL DEMONSTRATION DATA ACQUISITION FLIGHTS AT KJEVIK AIRPORT, KRISTIANSAND, NORWAY

Date	Run #	Type Run	AZ Angle	EL Angle	TRSB System	Start Distance	Initial/Constant Altitude
1/25/78	1	Approach	0°	4°	SC	10 nmi	I - 4,000 ft
	2	Approach	1° L	4°	SC	10 nmi	I - 4,000 ft
	3	Approach	2° L	3°	SC	10 nmi	I - 4,000 ft (1)
	4	Approach	0°	4°	BN	10 nmi	I - 3,900 ft
	5	Approach	1° L	4°	BN	10 nmi	I - 3,900 ft
	6	Approach	2° L	4°	BN	10 nmi	I - 3,900 ft
	7	Approach	1° R	4°	BN	10 nmi	I - 3,900 ft
	8	Approach	2° L	3°	BN	10 nmi	I - 3,100 ft
	9	Approach	1° L	3°	BN	10 nmi	I - 3,100 ft
	10	Approach	3° L	3°	BN	10 nmi	I - 3,100 ft
	11	Approach	2° L	2°	BN	10 nmi	I - 2,100 ft
	12	Orbit ±70° Counterclockwise	--	4°	BN	10 nmi	C - 3,900 ft
	13	Orbit ±70° Clockwise	--	4°	BN	10 nmi	C - 3,900 ft
	14	Orbit ±70° Counterclockwise	--	3°	BN	20 nmi	C - 3,100 ft
	15	Orbit ±70° Clockwise	--	4.5°	BN	20 nmi	C - 10,000 ft
	16	Orbit ±70° Counterclockwise	--	4.5°	BN	20 nmi	C - 10,000 ft
	17	Approach	2° L	3°	BN	10 nmi	I - 3,100 ft (4)
	18	Approach	1° L	3°	BN	10 nmi	I - 3,100 ft
	19	Approach	2° L	2.5°	BN	10 nmi	I - 2,600 ft
	20	Approach	0°	3°	BN	10 nmi	I - 3,100 ft
	21	Approach	0°	4°	BN	10 nmi	I - 3,900 ft
	22	Approach	1° L	4°	BN	10 nmi	I - 3,900 ft
	23	Approach	1° R	4°	BN	10 nmi	I - 3,900 ft (2 & 3)

TABLE 4 (continued)

Date	Run #	Type Run	AZ Angle	EL Angle	TRSB System	Start Distance	Initial/Constant Altitude
1/26/78	1	Approach	1° R	4°	BN	10 nmi	I - 4,000 ft (4)
	2	Approach	0°	4°	BN	10 nmi	I - 4,000 ft (4)
	3	Approach	1° L	4°	BN	10 nmi	I - 4,000 ft
	4	Approach	2° L	4°	BN	10 nmi	I - 4,000 ft
	5	Approach	0°	3°	BN	10 nmi	I - 3,100 ft
	6	Approach	1° L	3°	BN	10 nmi	I - 3,100 ft
	7	Approach	2° L	3°	BN	10 nmi	I - 3,100 ft
	8	Approach	2° L	2°	BN	10 nmi	I - 2,100 ft
	9	Radial	1° R	3°*	BN	15 nmi	C - 2,000 ft (3)
	10	Radial	0°	3°*	BN	10 nmi	C - 2,000 ft (3)
	11	Radial	1° L	3°*	BN	10 nmi	C - 2,000 ft (3)
	12	Radial	2° L	3°*	BN	10 nmi	C - 2,000 ft (3)
	13	Radial	3° L	3°*	BN	10 nmi	C - 2,000 ft (3)

*3° GP was set in TRSB equipment for radials at constant altitude.

Note 1: Run broken off at runway threshold due to traffic.
Note 2: No tracking at azimuth site with optical tracker due to darkness; tracker not equipped with illuminated cross-hair in sighting instrument. No tracking at elevation site due to a battery failure.
Note 3: Azimuth tracking only.
Note 4: Elevation tracking only.

Legend: L - Left of centerline
R - Right of centerline
I - Initial
C - Constant

TABLE 5

WEATHER SYNOPSIS FOR KJEVIK AIRPORT
KRISTIANSAND, NORWAY

JANUARY 23 THROUGH 26, 1978

January 23, 1978

Temperature at 7:00 am was 35°F and pressure 1007.3 millibars. Overcast, clouds 2,000 to 4,000 feet, with early morning snow beginning about 9:00 am, continuing throughout the day lowering ceilings to zero and visibility to 1/4 mile at times. Snow was continuous and mostly light; however, heavy at mid-day. Visibility remained 3 or less into the nighttime hours with ceilings above 3,500 feet. Wind direction was variable, but mostly east to southeast with speeds from 0 to 11 knots.

January 24, 1978

Temperature at 7:00 am was 32°F and pressure 993.4 millibars. Overcast, clouds 2,000 to 4,000 feet in the early morning with visibility of 20 miles. Snow began about 3:00 pm and continued to midnight. The sky was obscured from the beginning of the snow to midnight. The visibility was reduced to 1-1/8 miles. The visibility increased, however, did not reach 3 miles through midnight. Wind direction was mostly east 8 to 16 knots.

January 25, 1978

Temperature at 7:00 am was near freezing and at 7:00 pm, was 26°F. Overcast skies with ceilings above 2,000 feet the entire day. Period of light snow from 7:00 to 8:00 am; visibility at this time was above 5 miles; the visibility improved throughout the day to 13 miles or more. Pressure at 7:00 am was 993.5 millibars. Wind direction was mostly north to northeast at 0 to 12 knots.

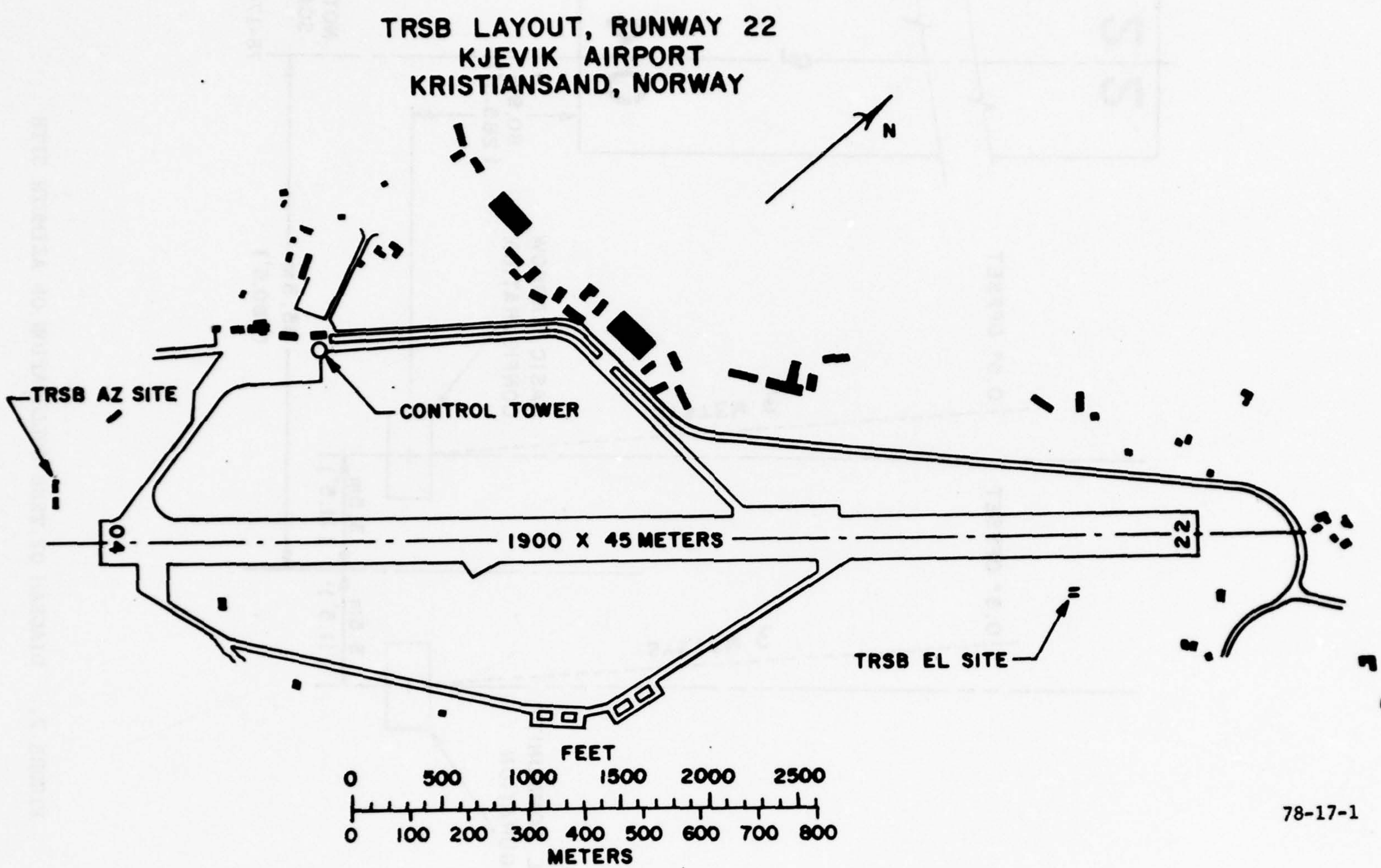
January 26, 1978

Temperature at 7:00 am was 23° and pressure 999.3 millibars. Temperature at 7:00 pm was 23°F and the pressure was 1001.5 millibars. Scatterted to broken clouds with ceilings above 2,000 feet and visibility above 12 miles during daylight hours. Very little change in ceiling height toward midnight; however, clouds increased and a period of light snow began about 8:00 pm and continued to midnight. Ceilings became overcast at that time, but visibility remained above 5 miles. Wind direction was mostly east to northeast with speeds from 0 to 5 knots.

TABLE 6.

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



78-17-1

FIGURE 1. PLAN VIEW OF RUNWAY

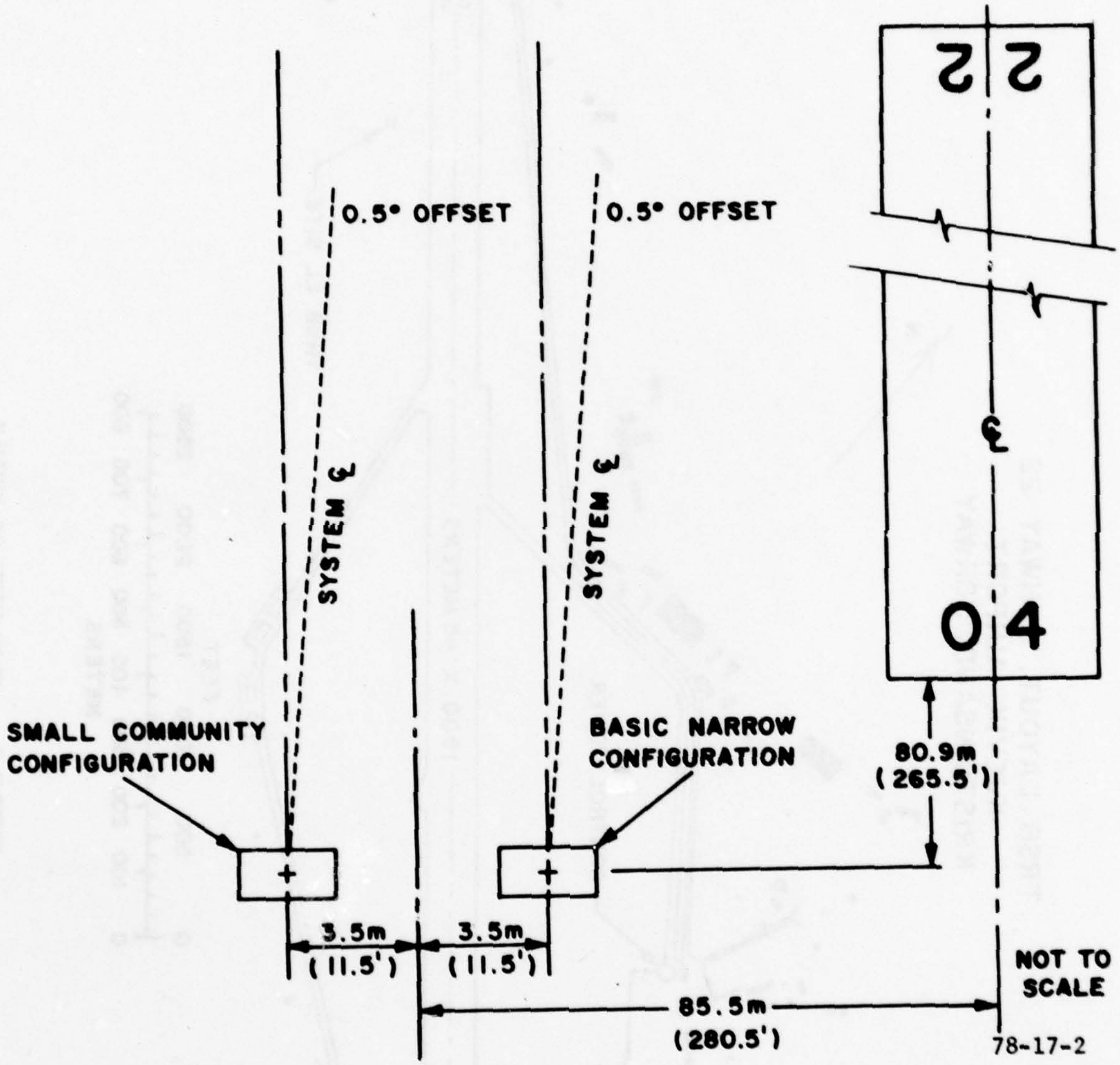


FIGURE 2. DIAGRAM OF TRSB COLLOCATION ON AZIMUTH SITE

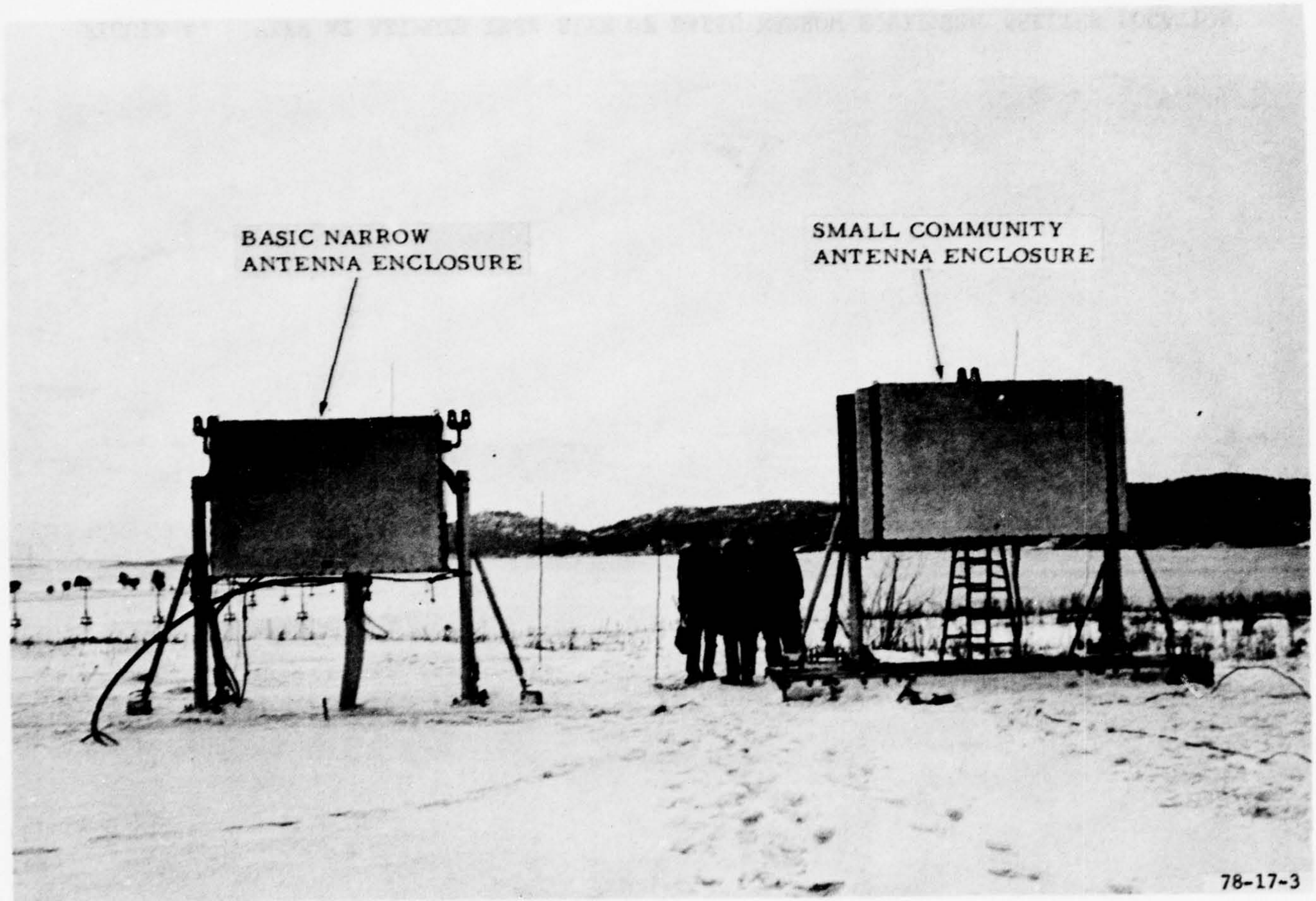


FIGURE 3. TRSB AZIMUTH SUBSYSTEMS INSTALLATION

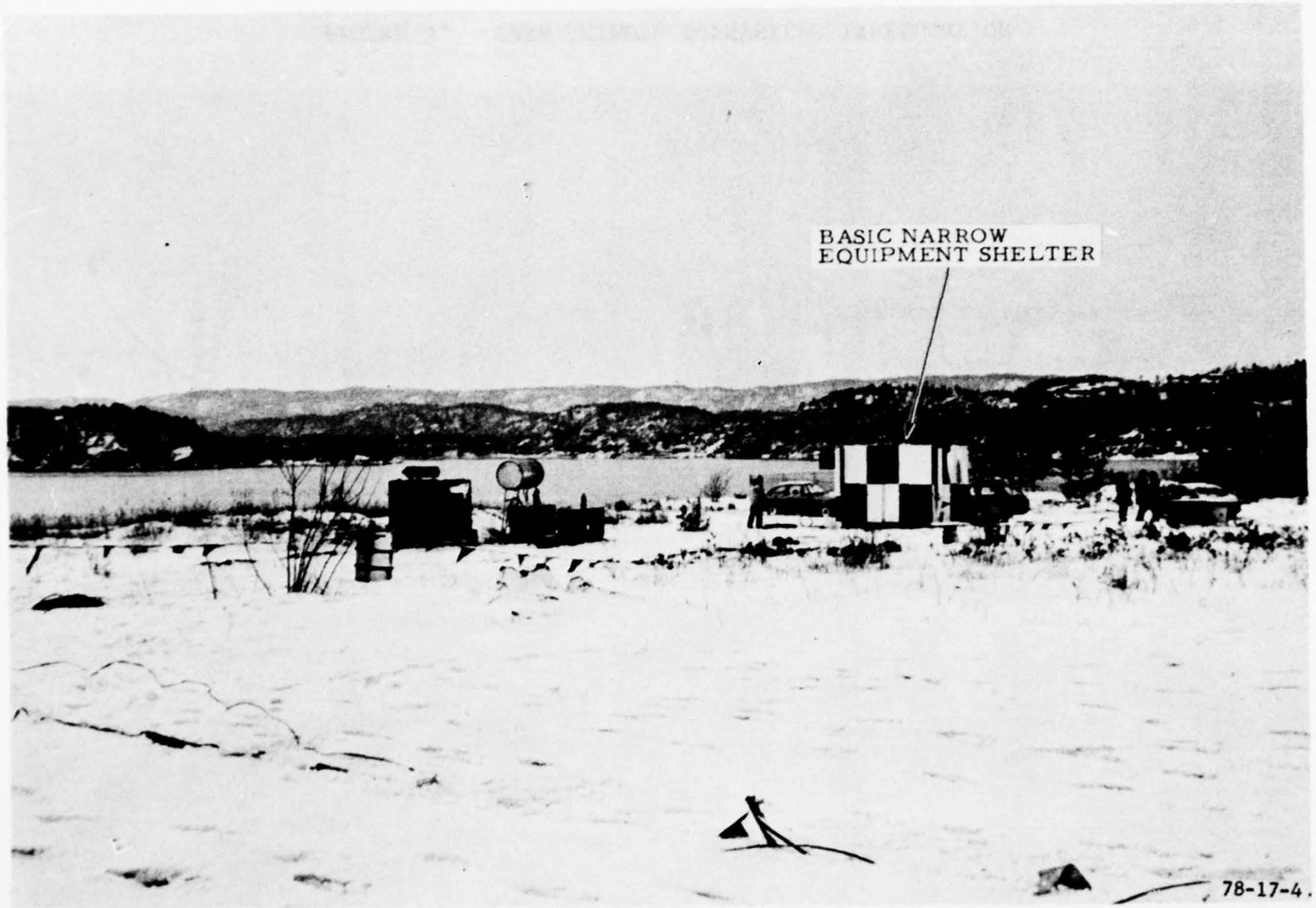


FIGURE 4. VIEW AT AZIMUTH TRSB SITE OF BASIC NARROW EQUIPMENT SHELTER LOCATION

FIGURE 5. OVERALL VIEW OF TRSB AZIMUTH SITE SHOWING KRISTIANSAND FIORD IN THE BACKGROUND

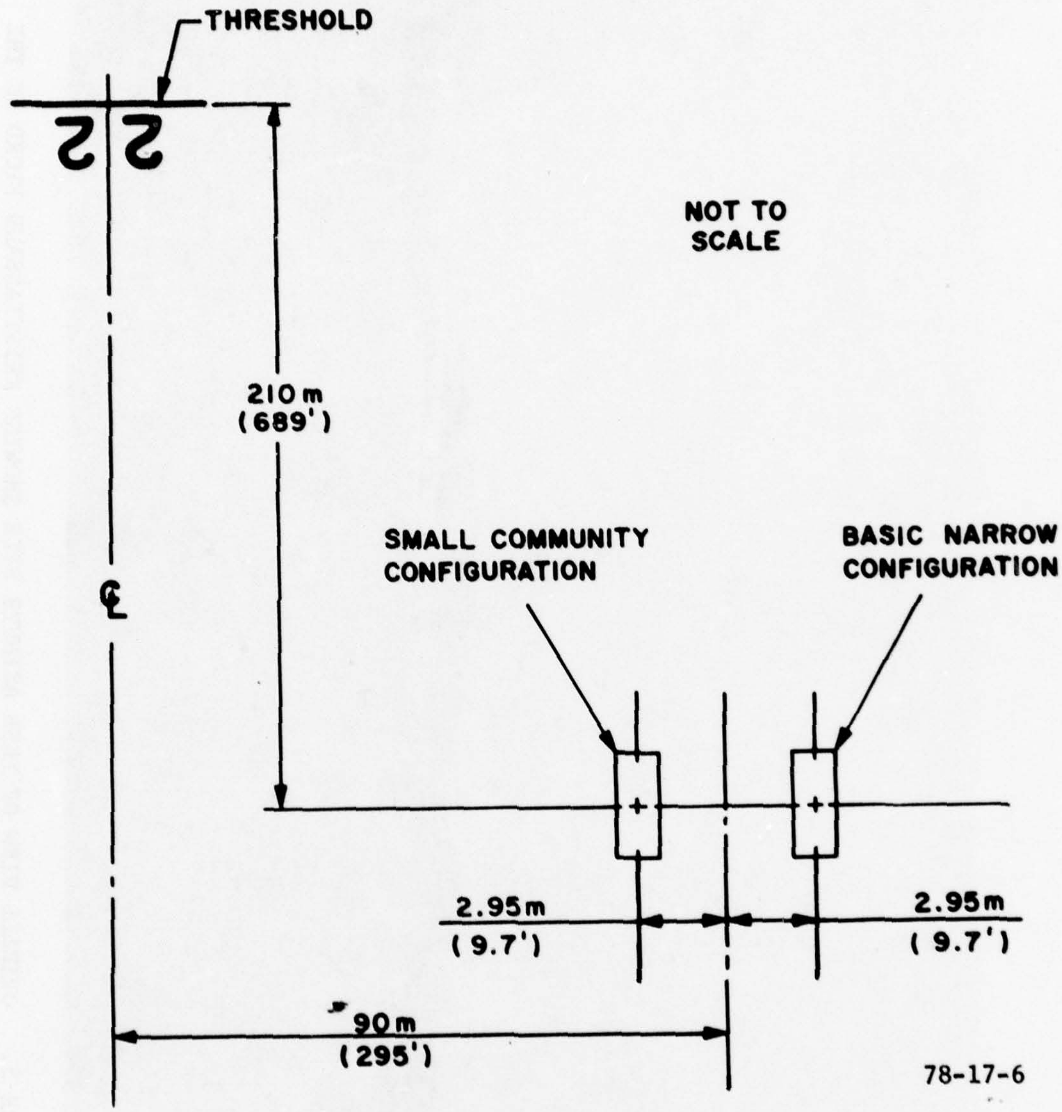


FIGURE 6. DIAGRAM OF TRSB COLLOCATION ON ELEVATION SITE

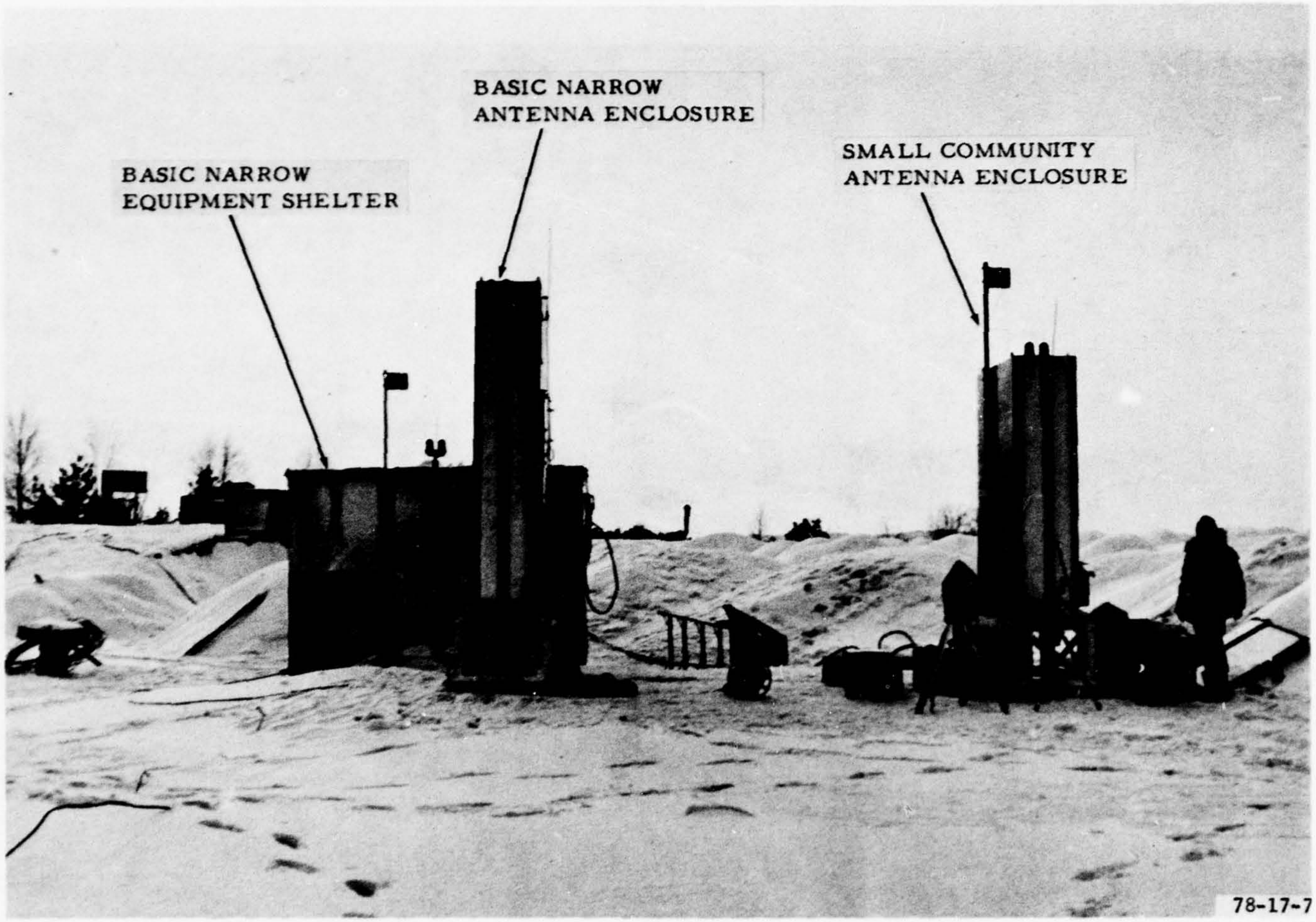


FIGURE 7. TRSB ELEVATION SUBSYSTEMS INSTALLATION

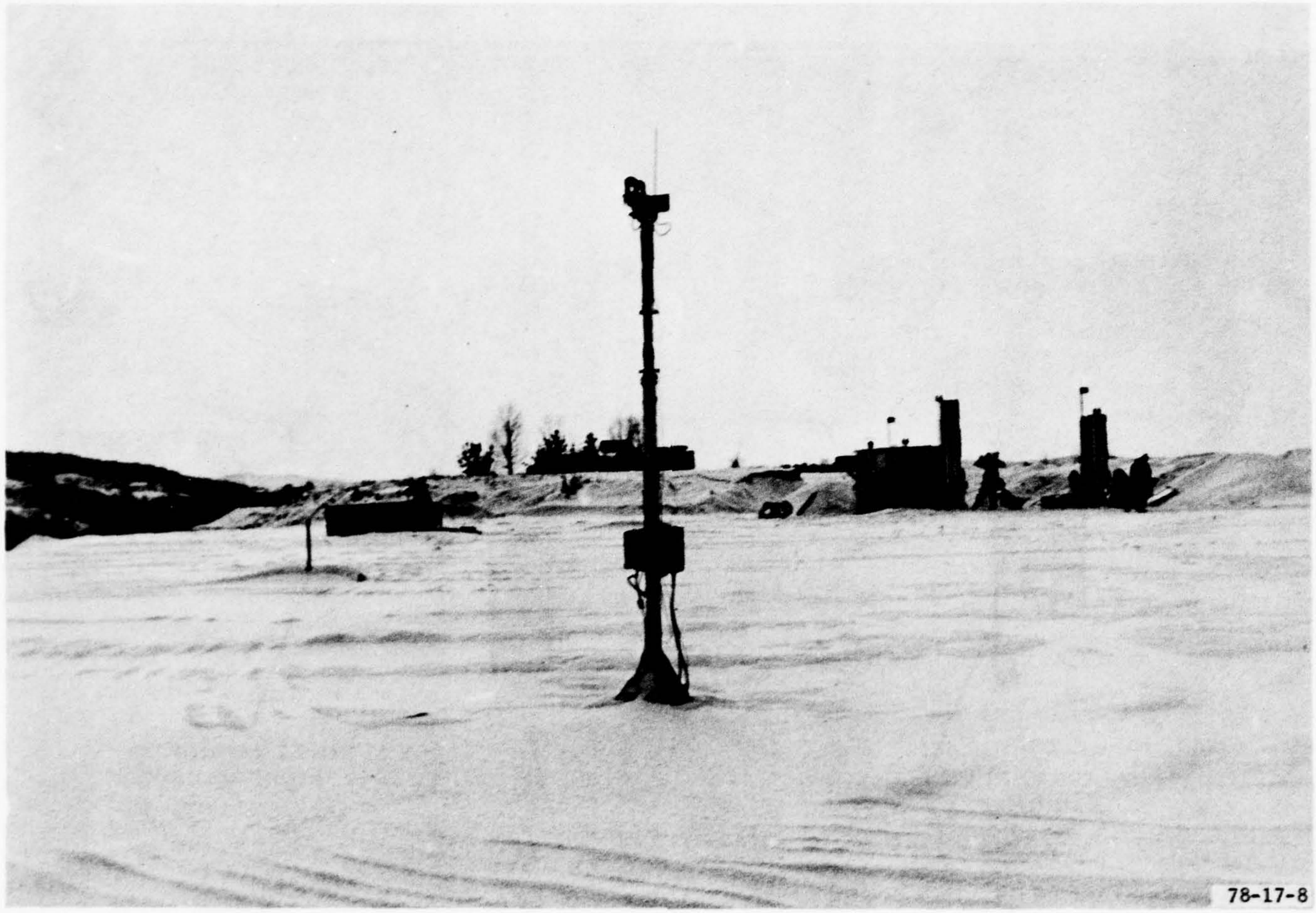


FIGURE 8. OVERALL VIEW OF TRSB ELEVATION SITE SHOWING THE BASIC NARROW FAR FIELD MONITOR IN THE FOREGROUND

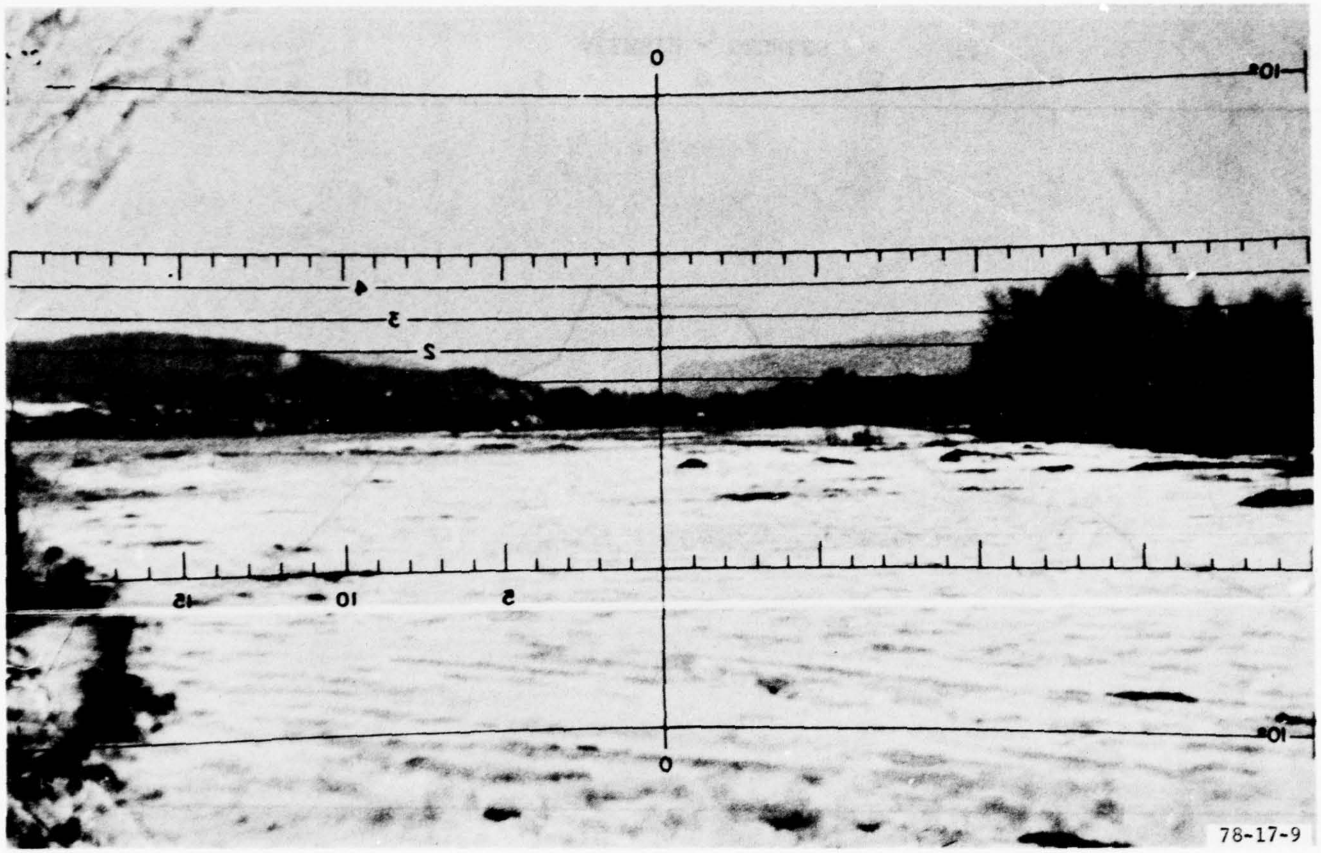


FIGURE 9. VIEW OF KJEVIK AIRPORT RUNWAY 22 APPROACH SHOWING NATURAL TERRAIN OBSTRUCTIONS

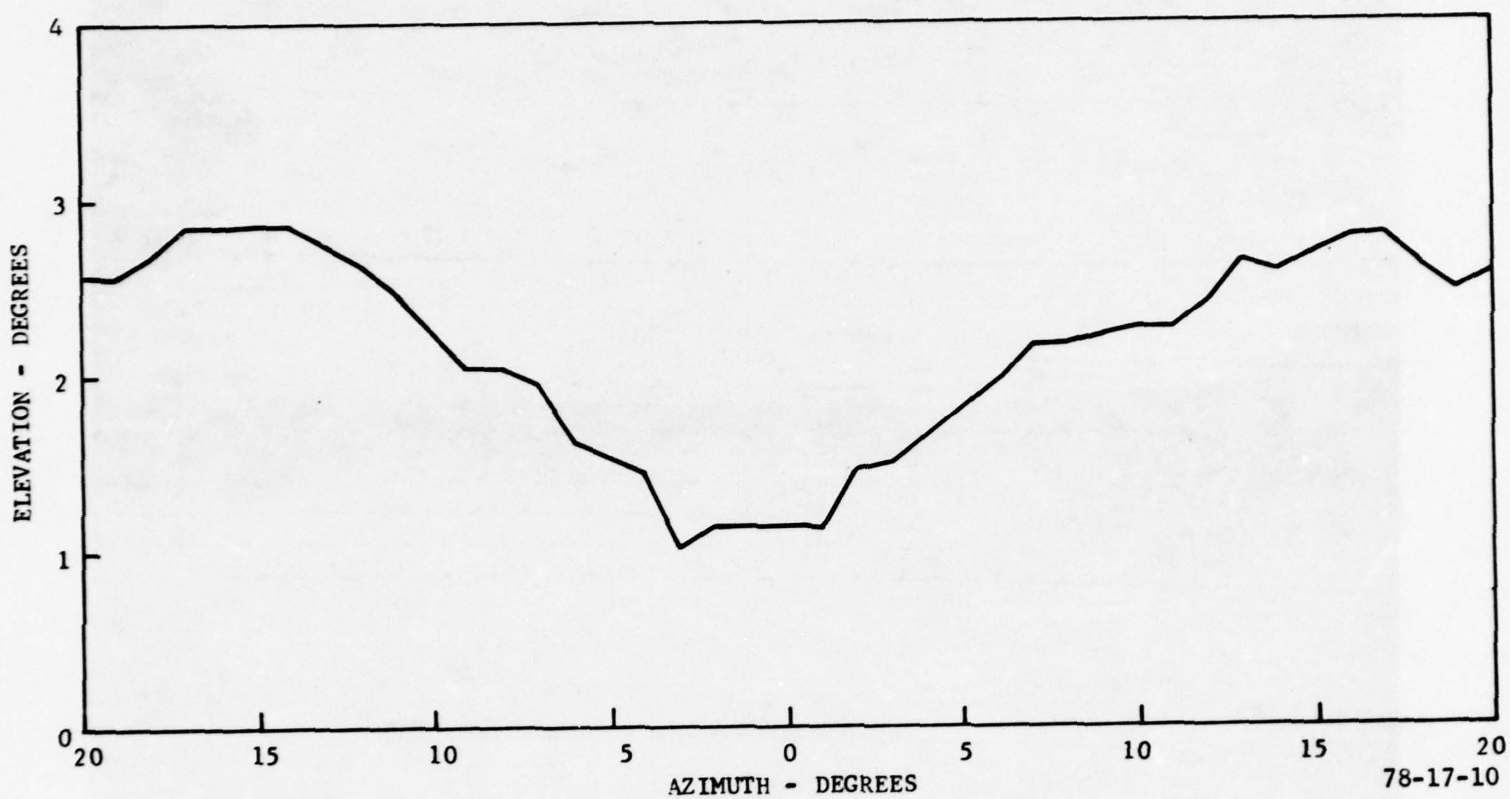


FIGURE 10. TERRAIN CLEARANCE ANGLES FOR APPROACH TO RUNWAY 22

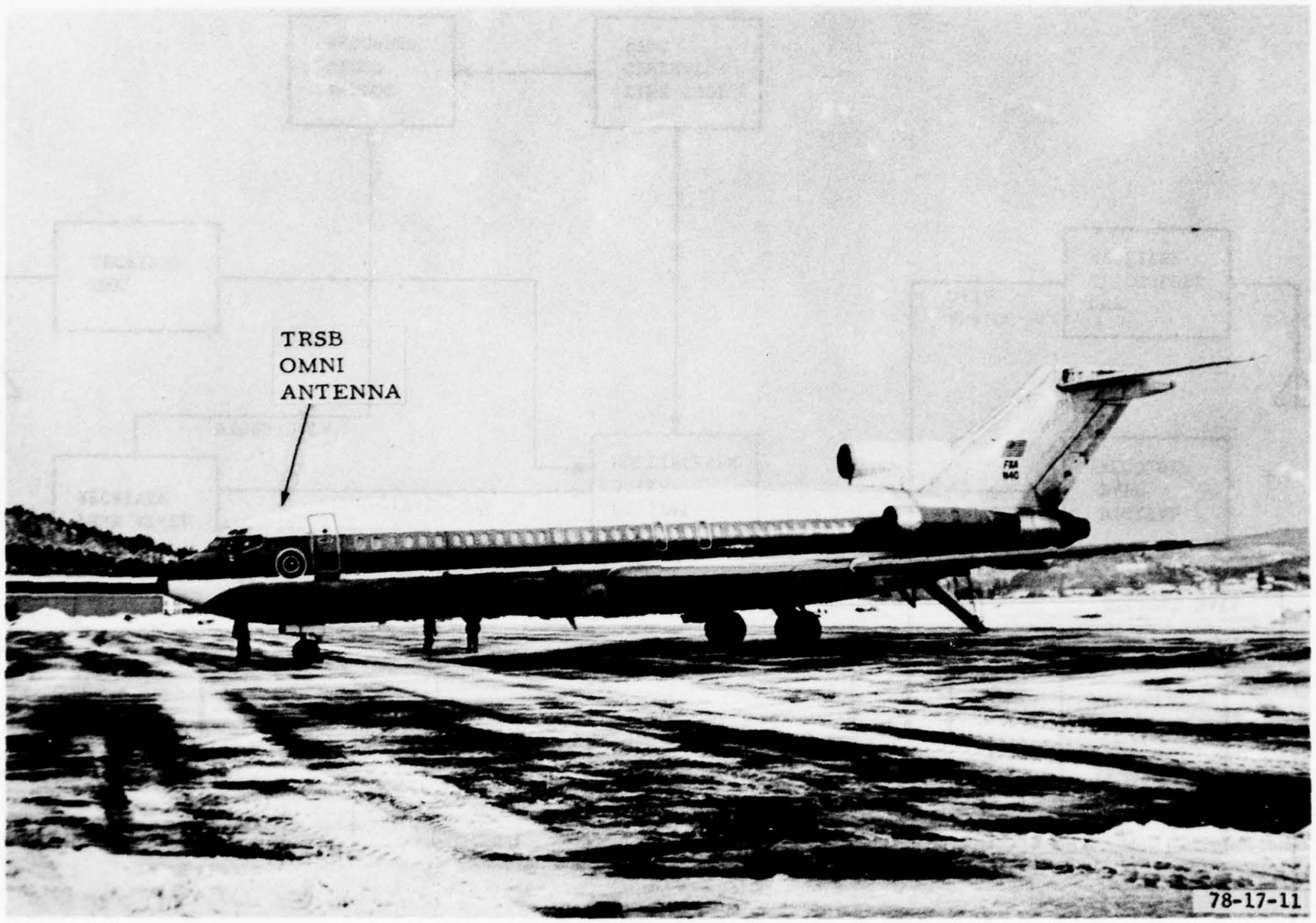


FIGURE 11. FAA BOEING 727 TRSB TESTBED AIRCRAFT AT KJEVIK AIRPORT, KRISTIANSAND, NORWAY

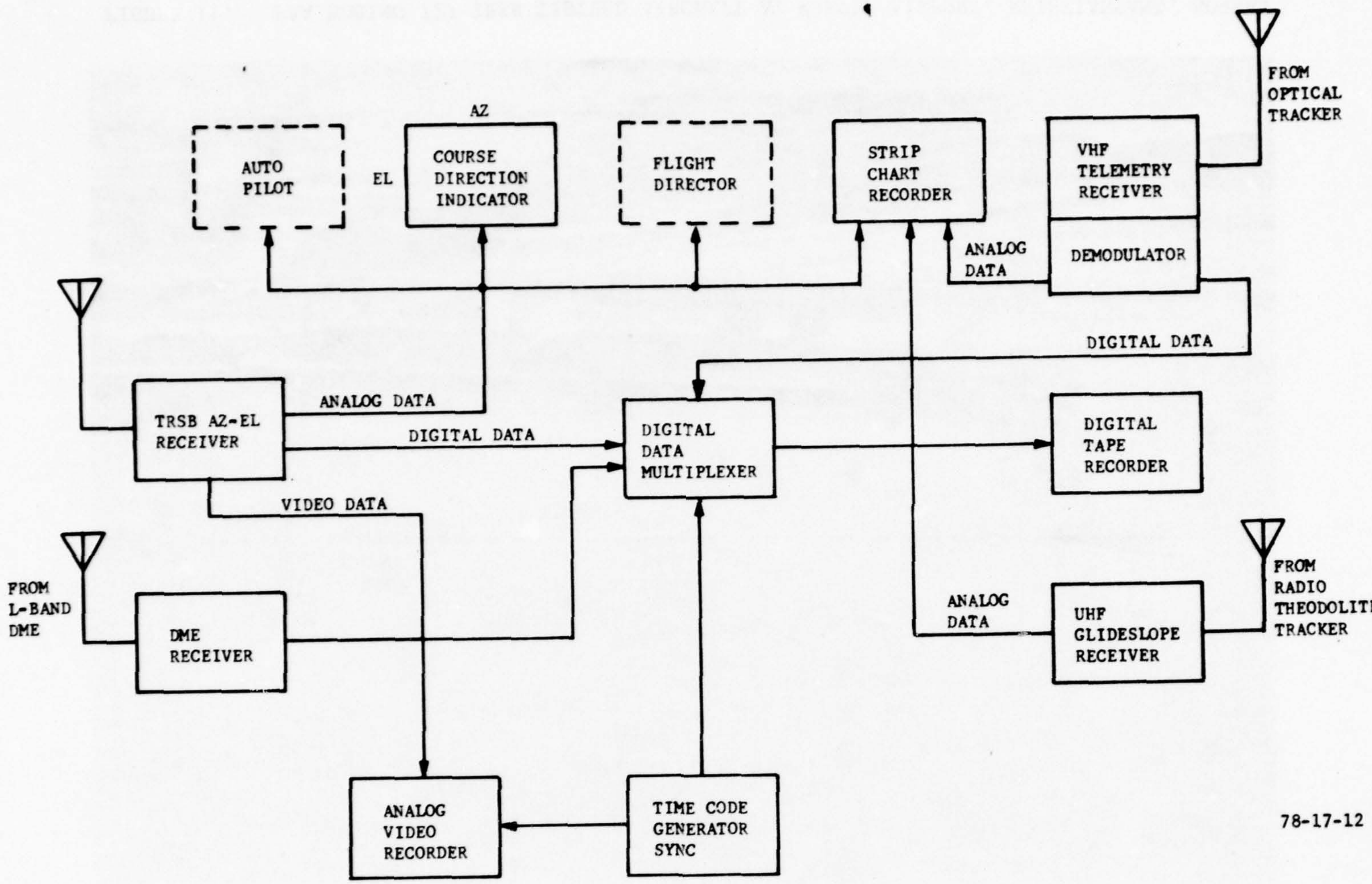


FIGURE 12. TRSB AIRBORNE TESTBED INSTRUMENTATION EMPLOYED AT KJEVIK AIRPORT, KRISTIANSAND, NORWAY

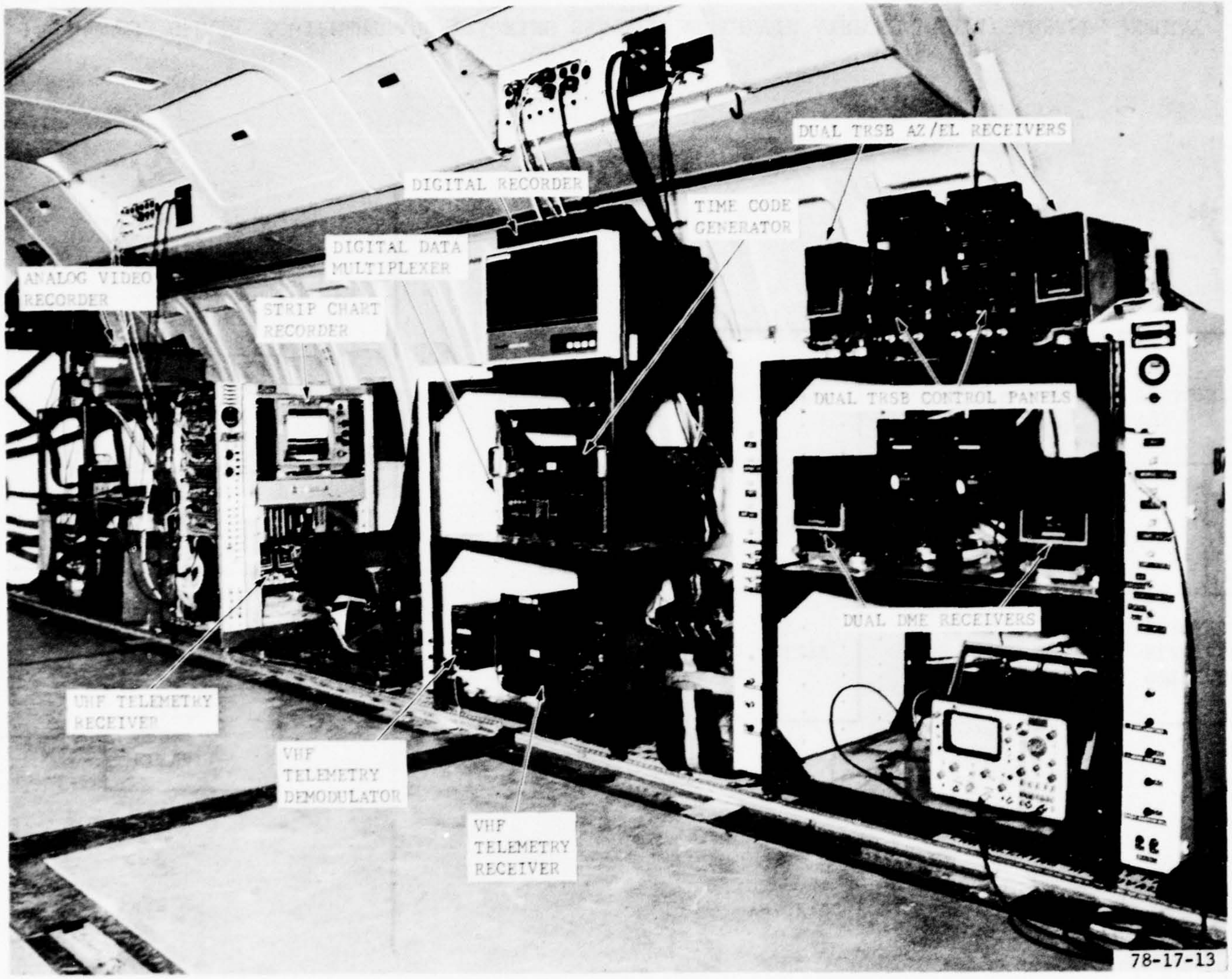


FIGURE 13. VIEW OF TRSB EQUIPMENT AND INSTRUMENTATION CONFIGURATION IN THE CABIN SECTION OF THE BOEING 727 TESTBED AIRCRAFT

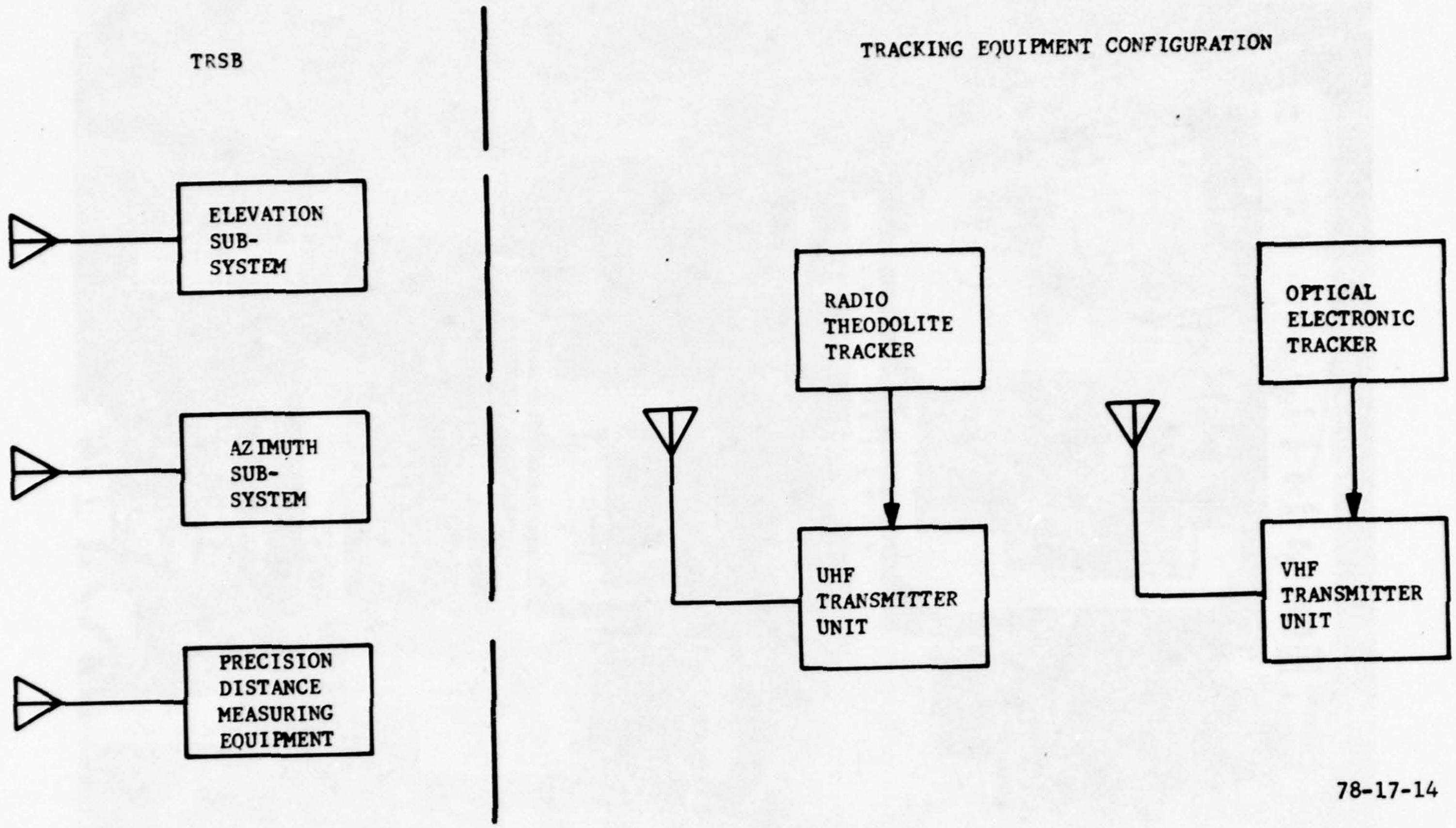


FIGURE 14. TRSB GROUND EQUIPMENT AND TRACKING SYSTEMS AT KJEVIK AIRPORT, KRISTIANSAND, NORWAY

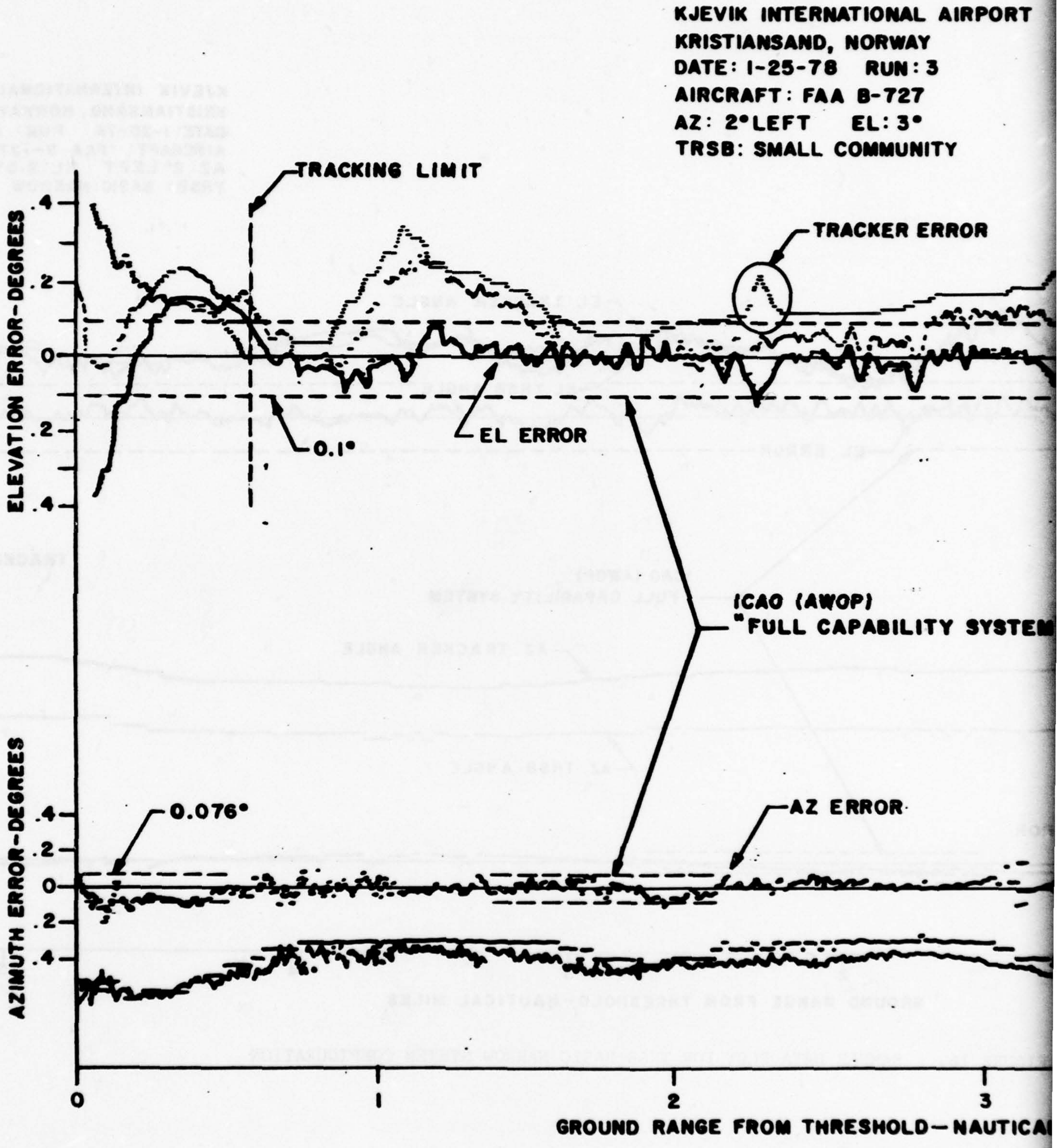
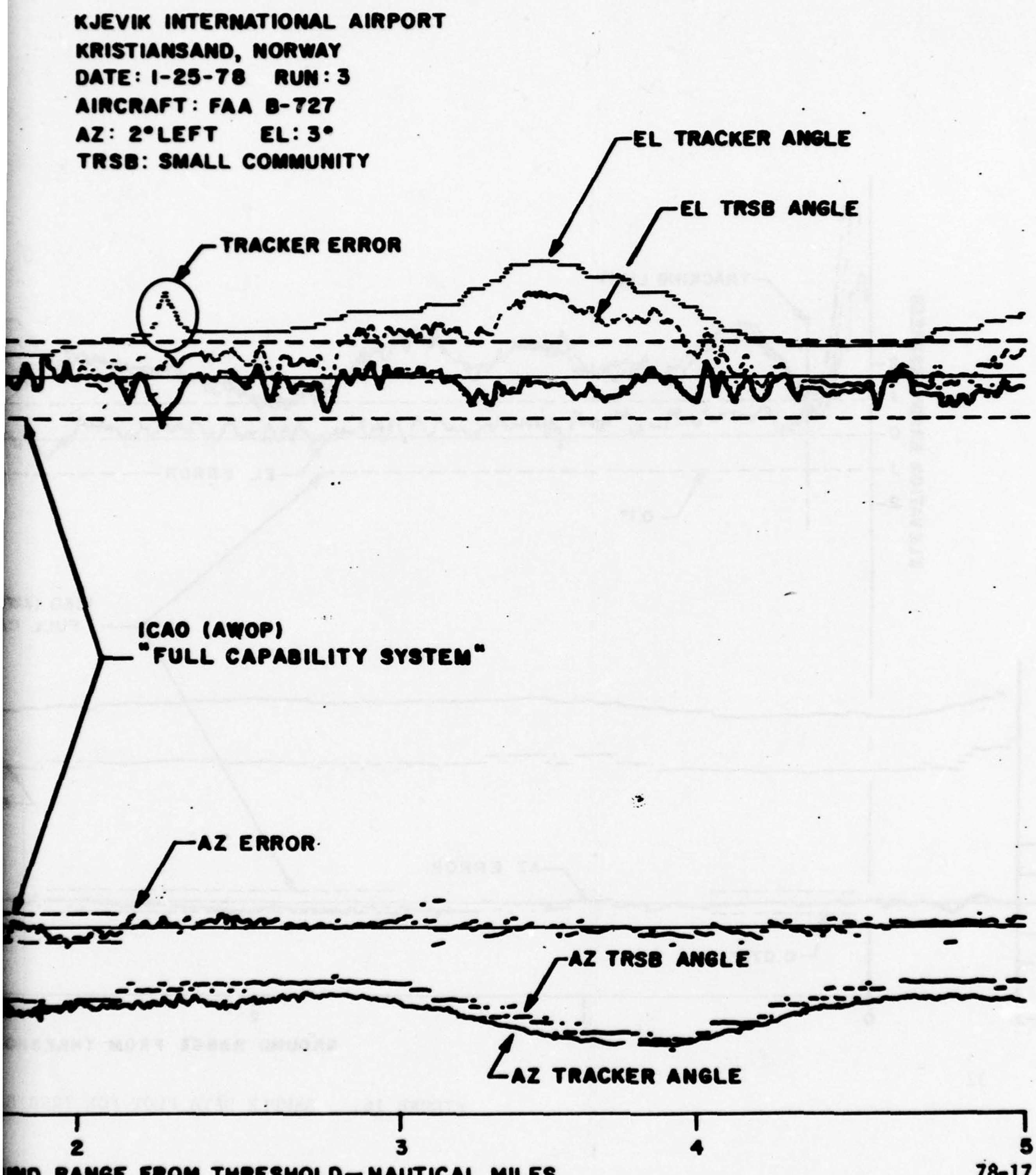


FIGURE 15. SAMPLE DATA PLOT FOR TRSB SMALL COMMUNITY S



78-17

MPLE DATA PLOT FOR TRSB SMALL COMMUNITY SYSTEM CONFIGURATION

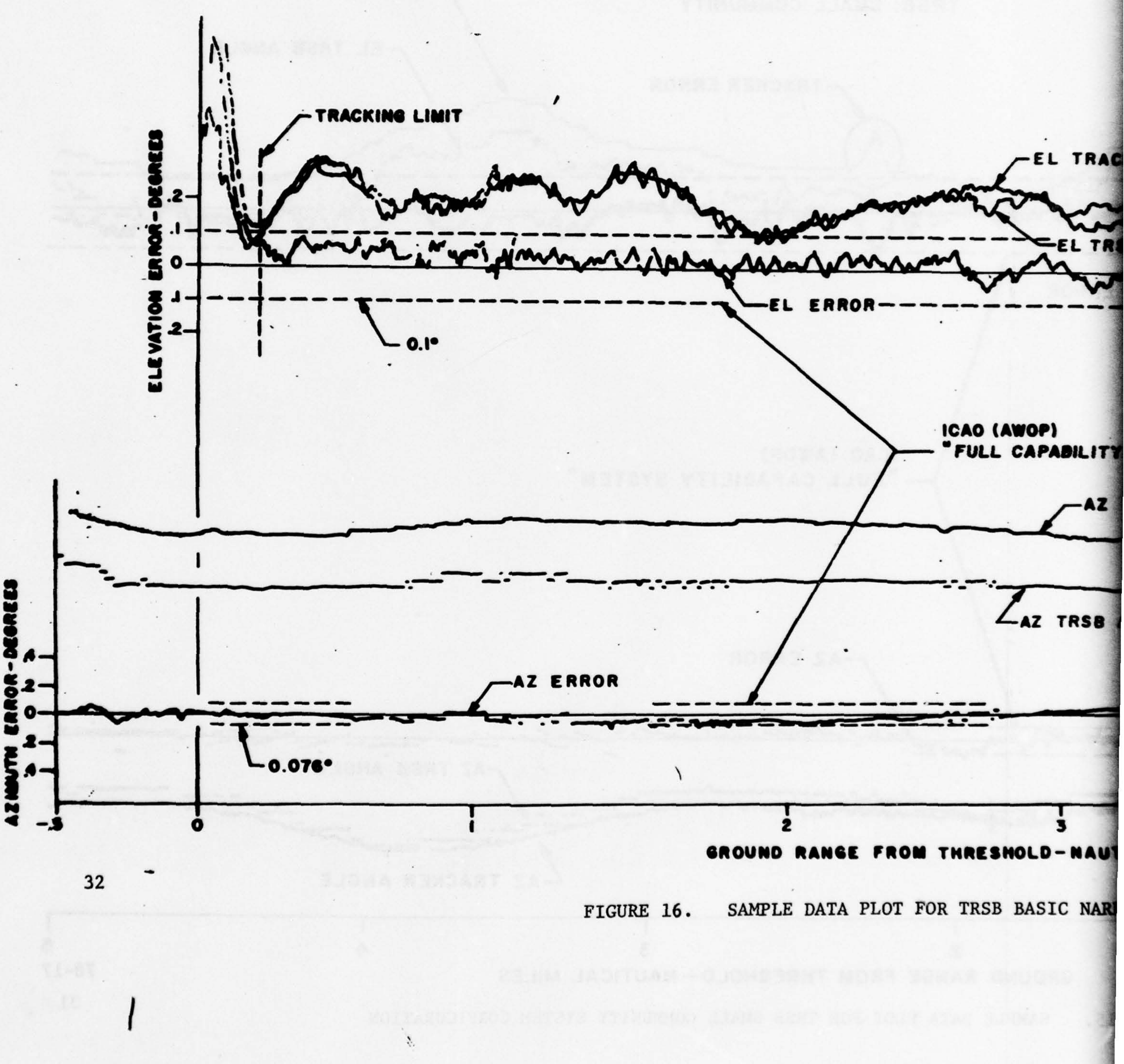
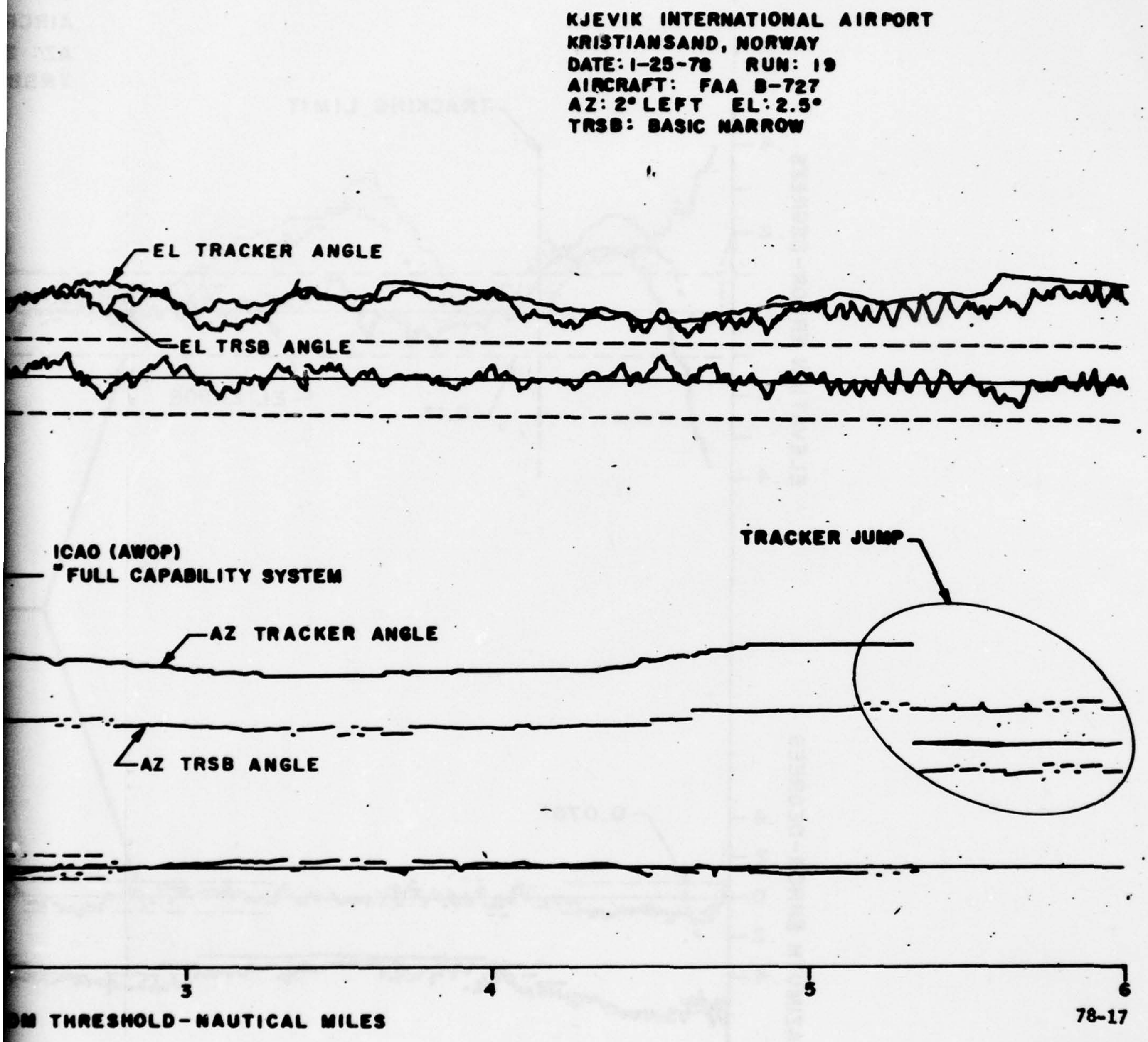


FIGURE 16. SAMPLE DATA PLOT FOR TRSB BASIC NAR



FOR TRSB BASIC NARROW SYSTEM CONFIGURATION

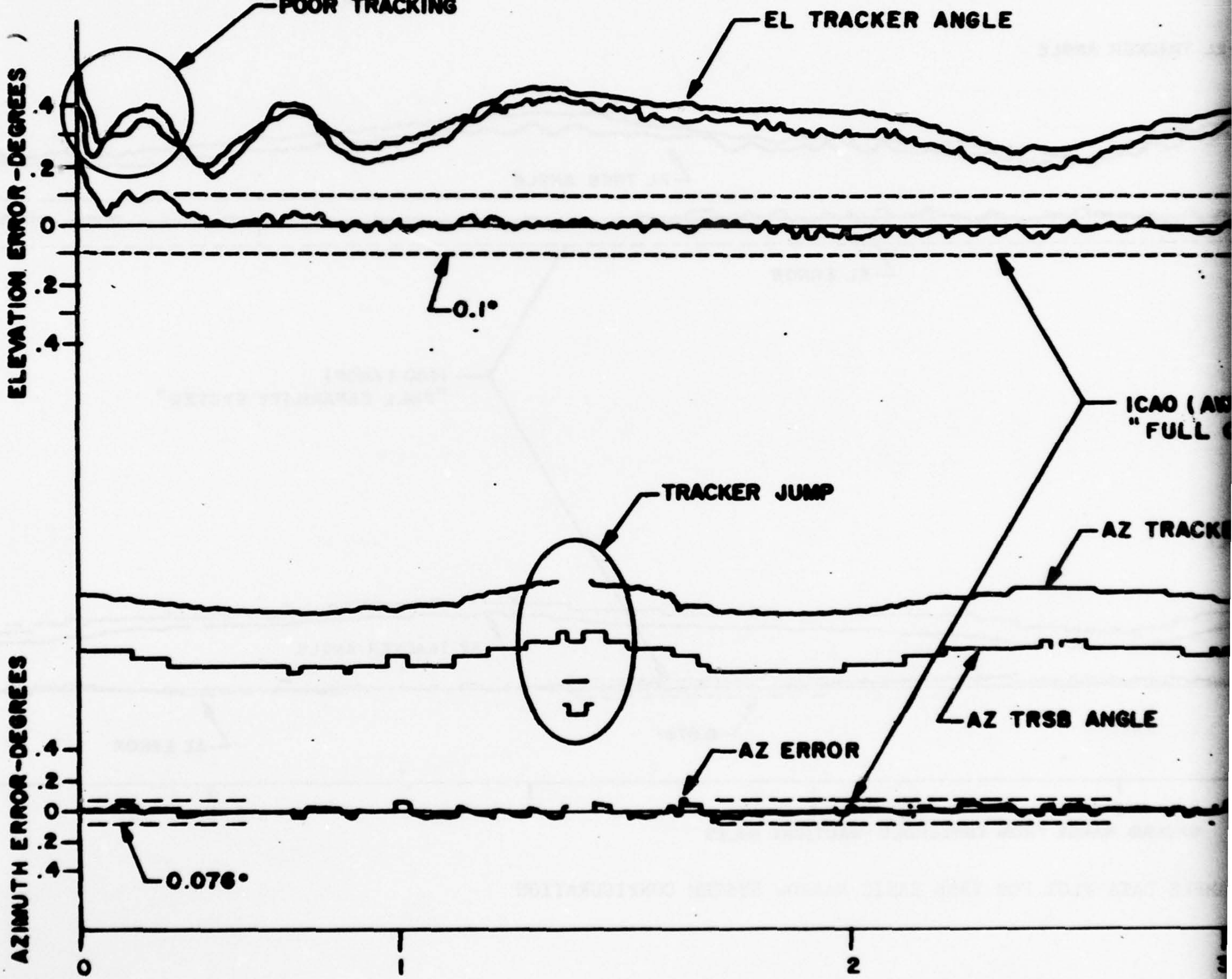
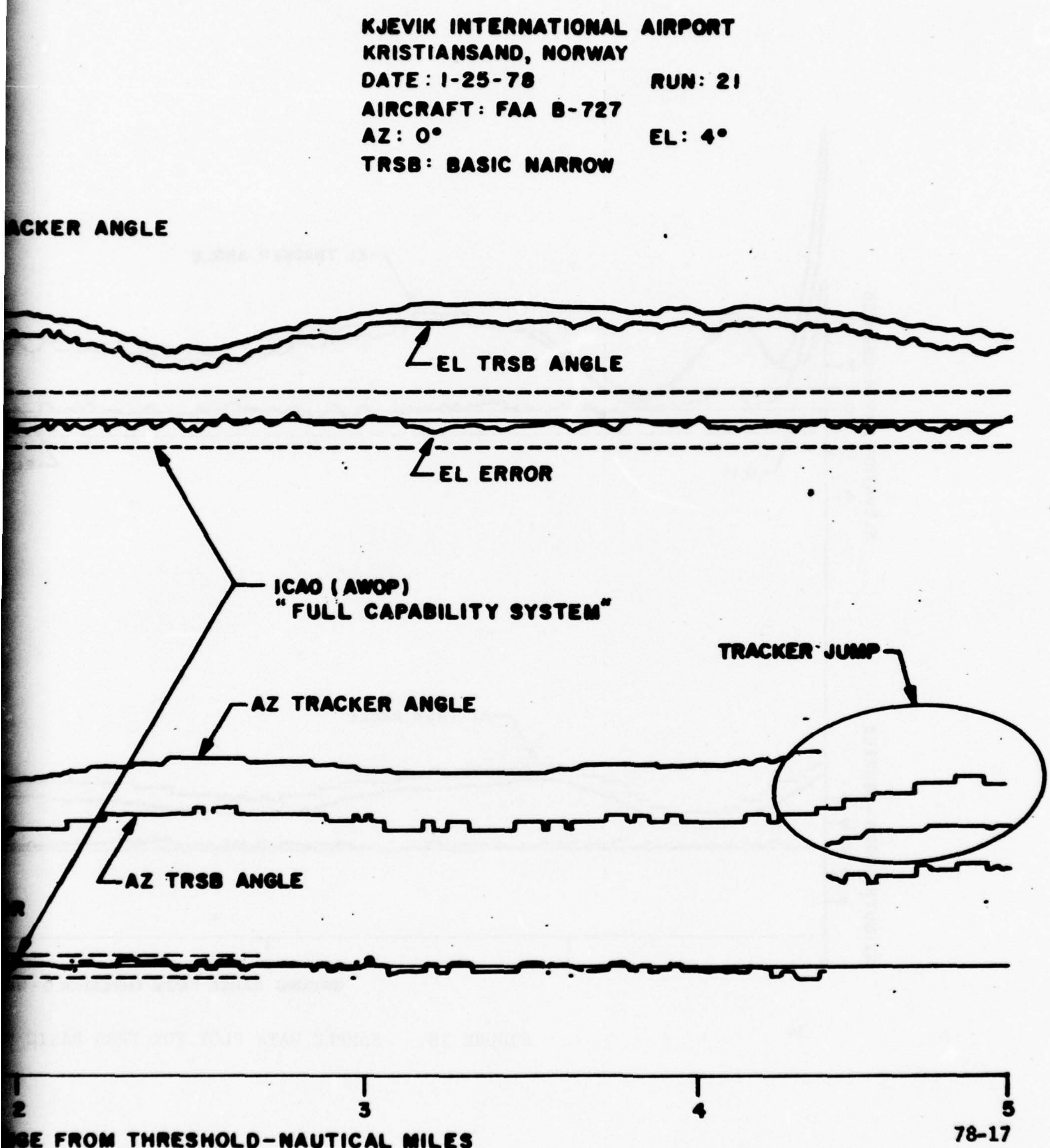


FIGURE 17. SAMPLE DATA PLOT FOR TRSB BASIC NARROW



ATA PLOT FOR TRSB BASIC NARROW SYSTEM CONFIGURATION

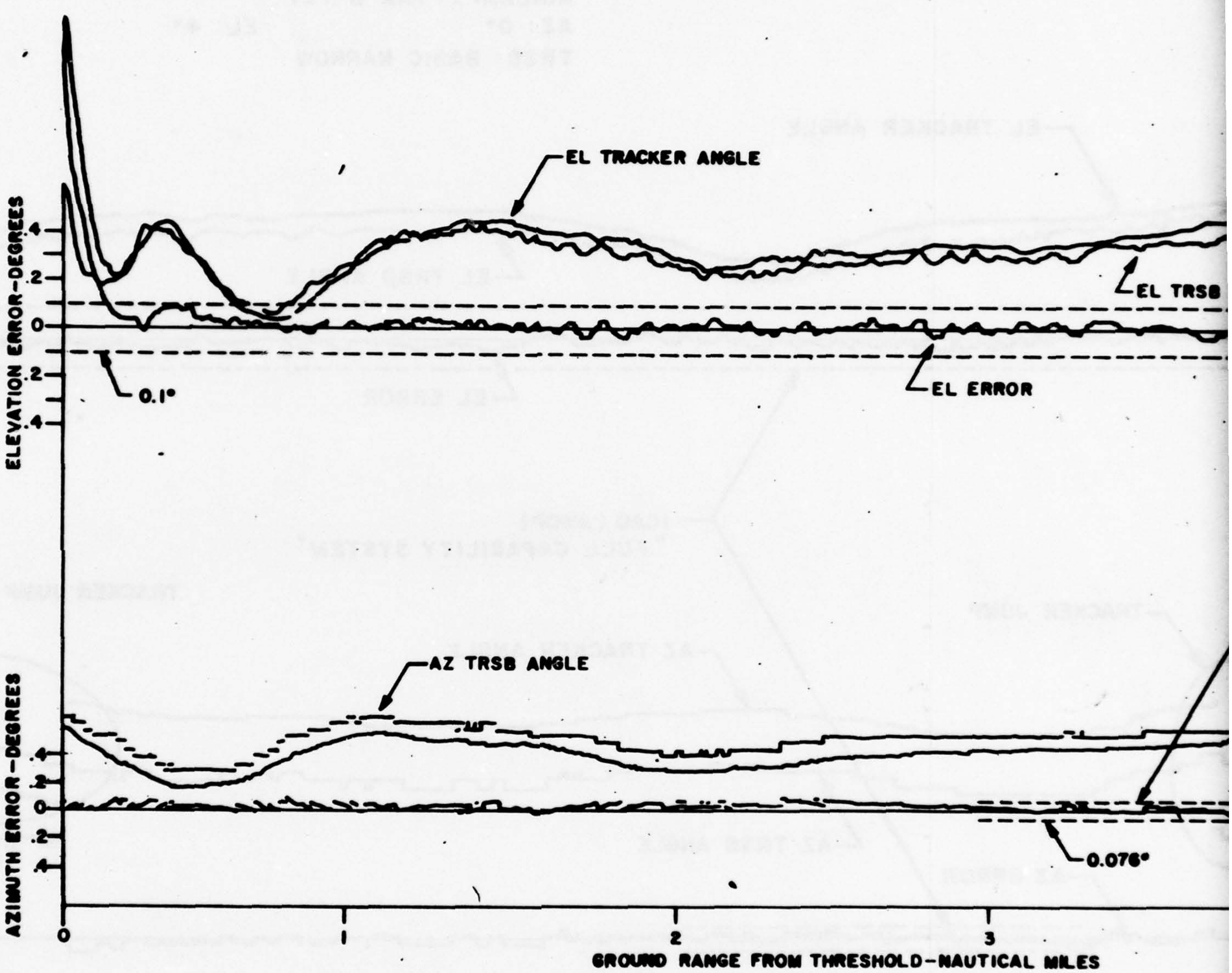
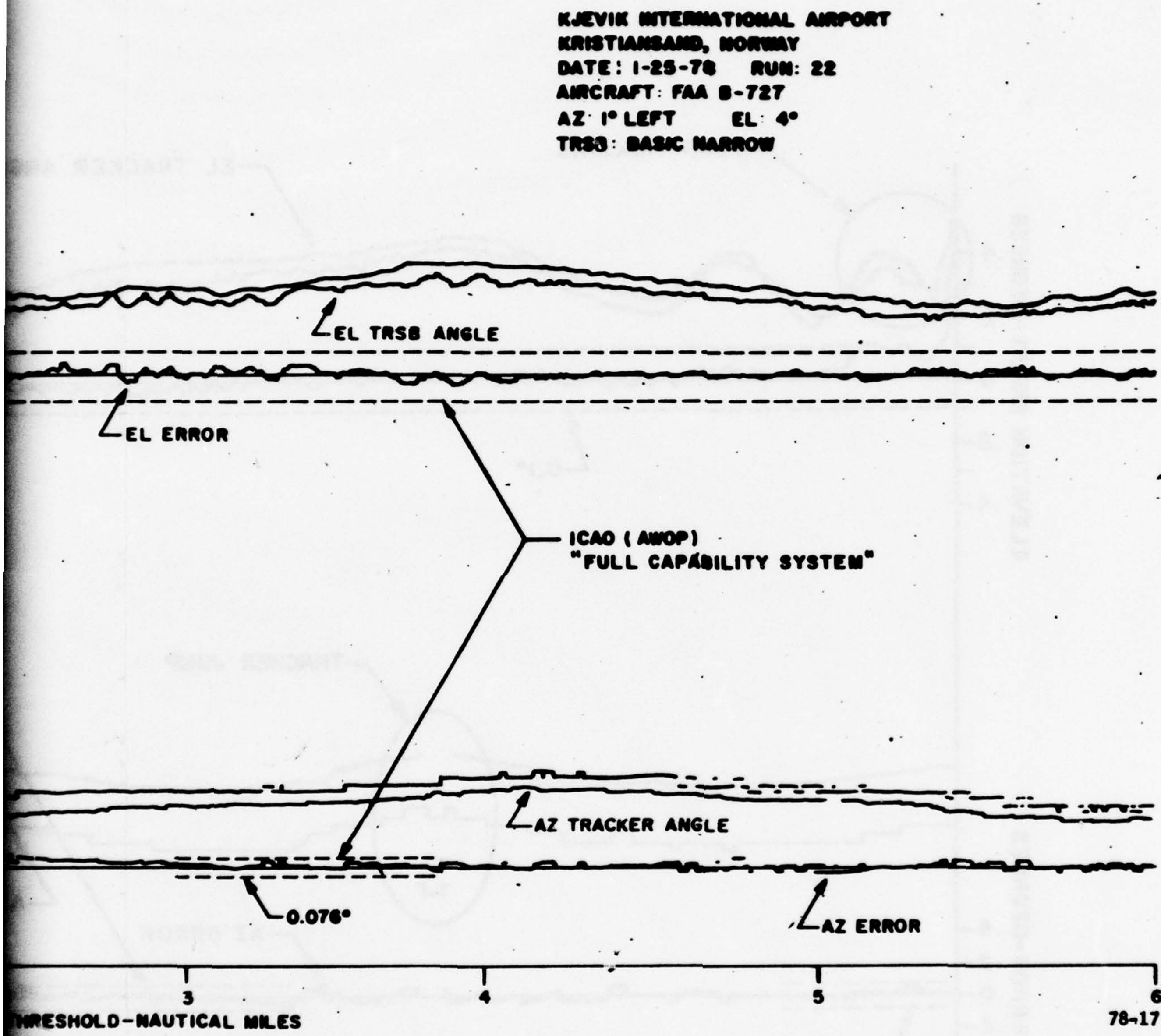


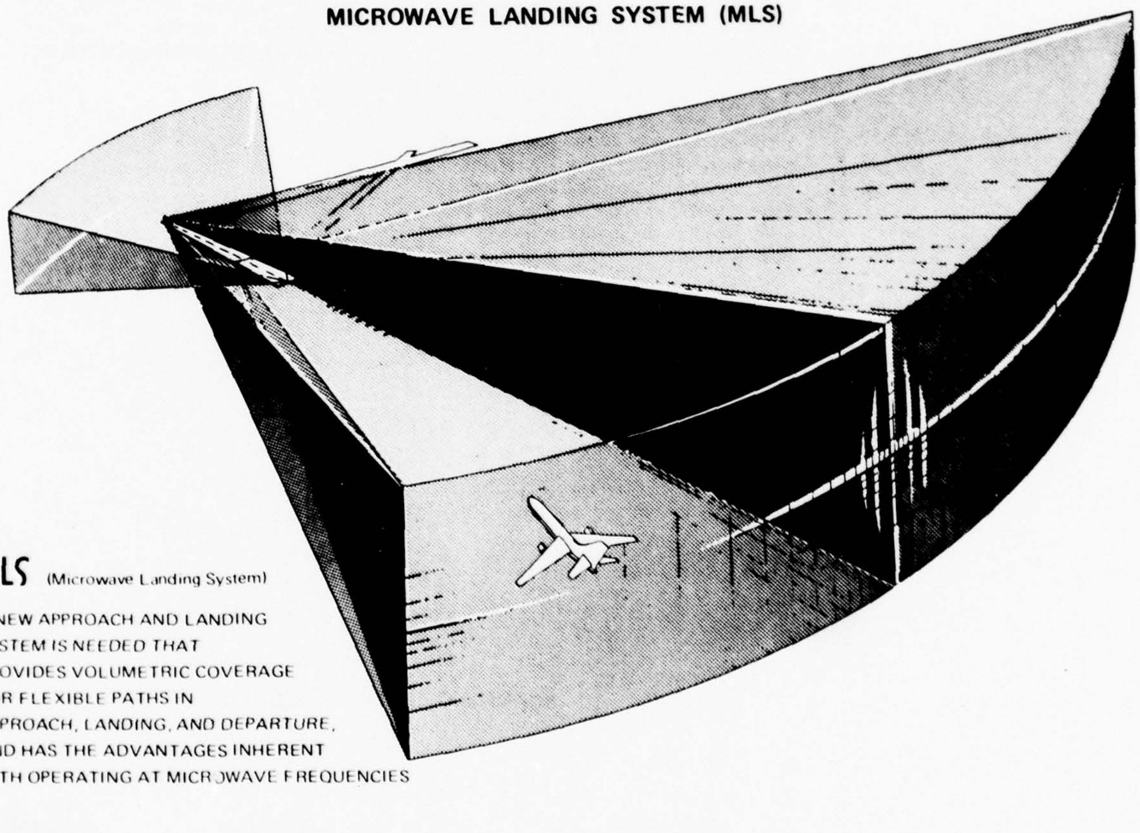
FIGURE 18. SAMPLE DATA PLOT FOR TRSB BASIC NARROW SYSTEM CONFIGUR



TRSB BASIC NARROW SYSTEM CONFIGURATION

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

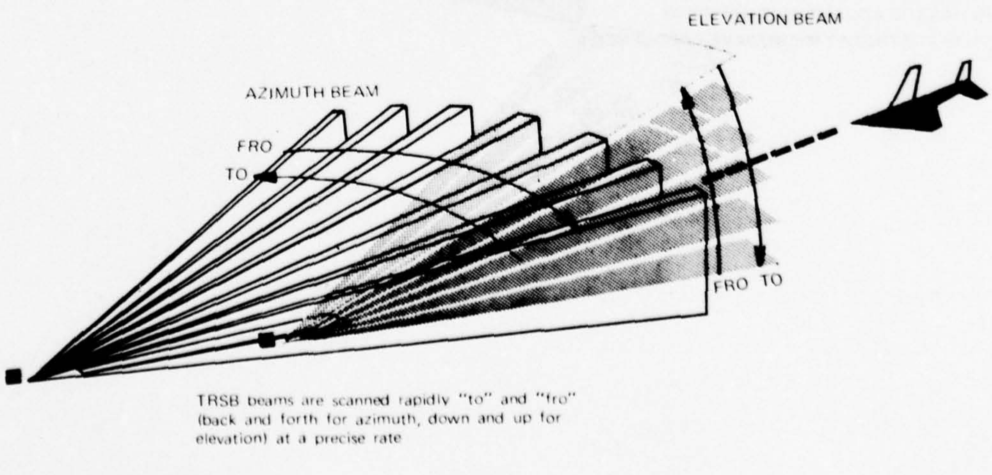
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data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



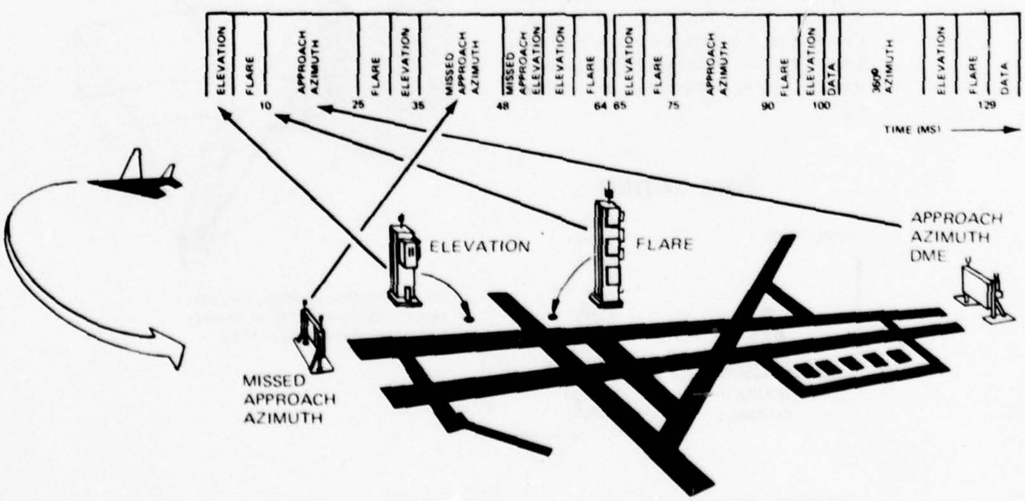
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

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.

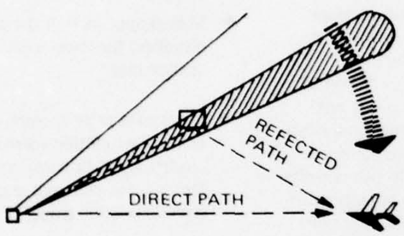


The TRSB signal offers maximum flexibility to meet unique user requirements

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.

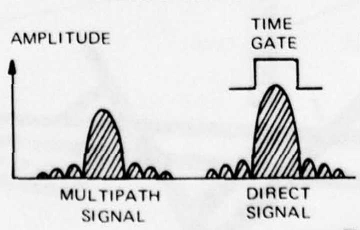
THERE ARE TWO TYPES OF MULTIPATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival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



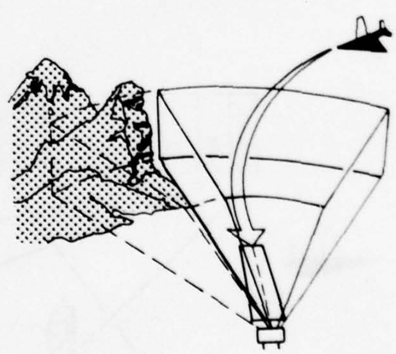
Time gating ensures that the correct signal is tracked, not the reflected one

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.

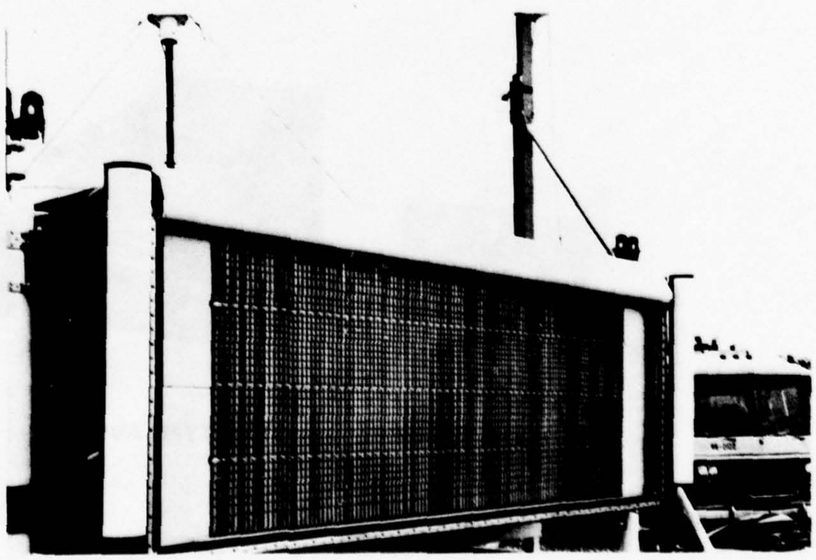
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide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



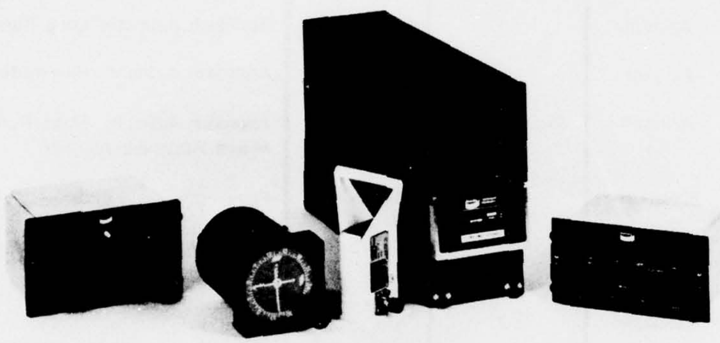
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

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.

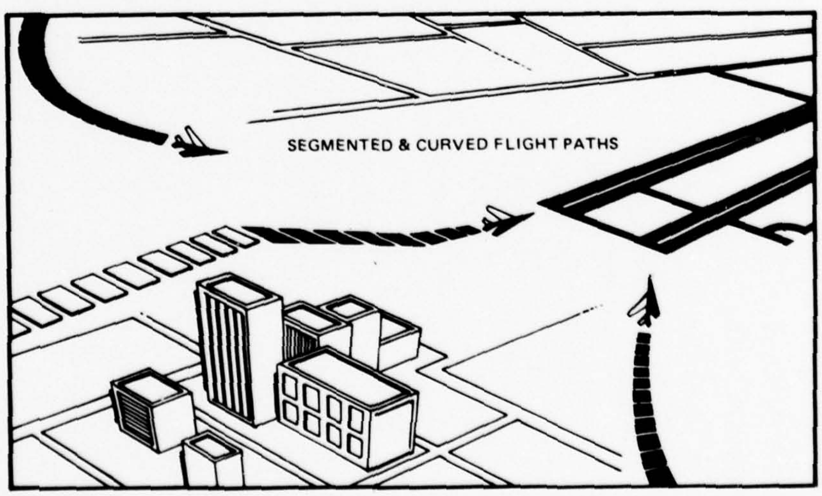
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

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.

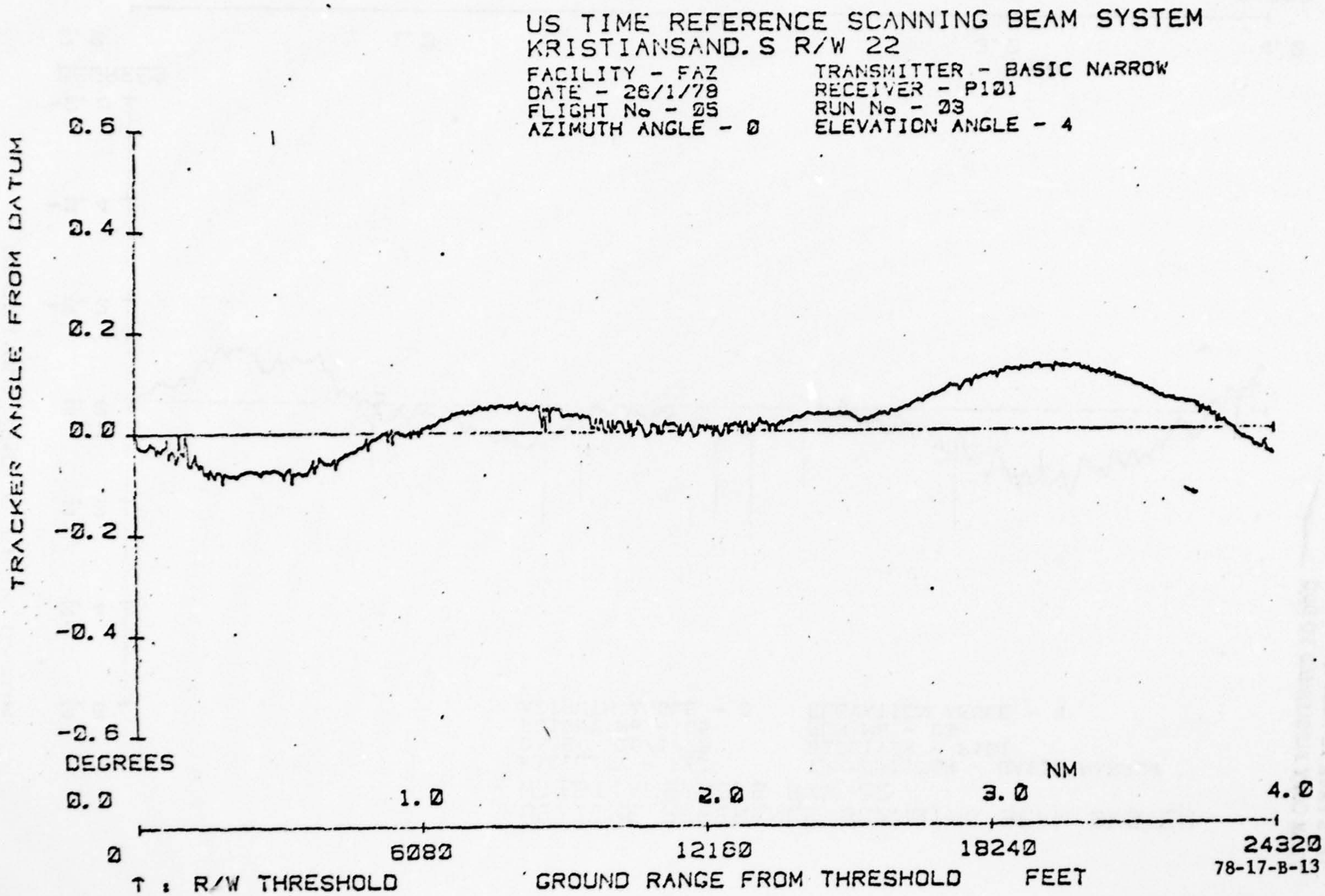
TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).

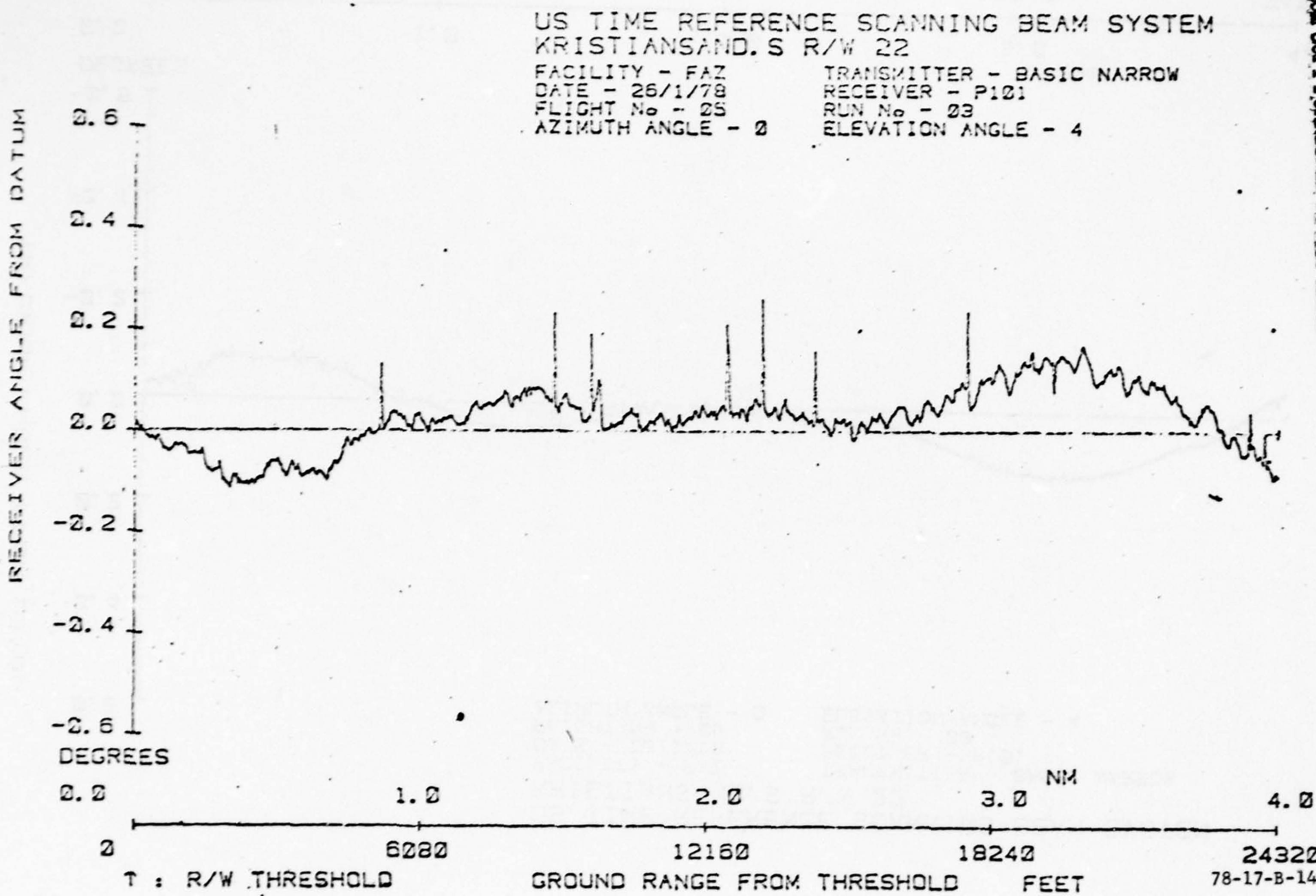


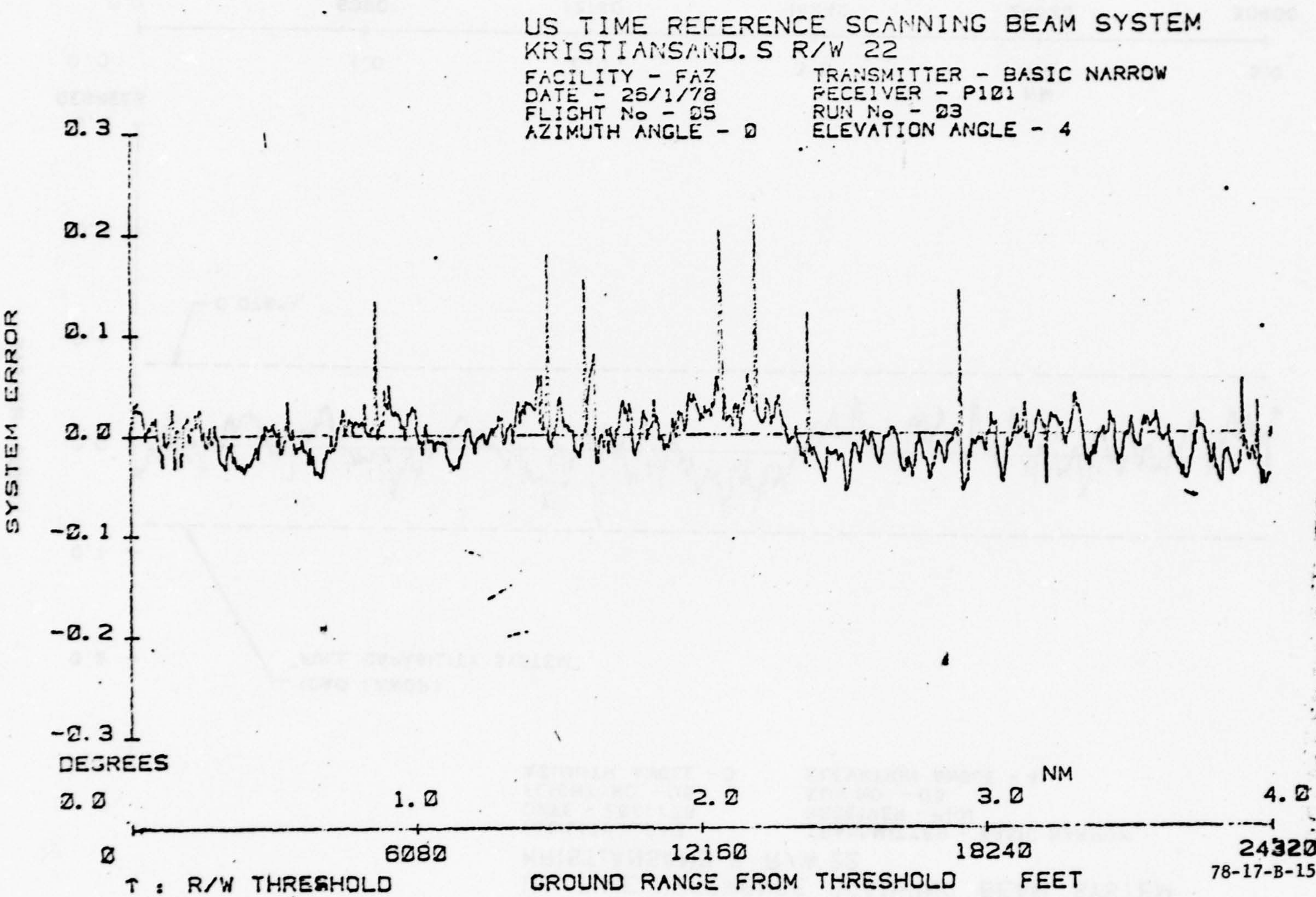
TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout

APPENDIX B

U.K. TRSB DATA


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - FAZ
DATE - 26/1/78
FLIGHT No - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 03
ELEVATION ANGLE - 4
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
FEET
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
78-17-B-13


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - FAZ
DATE - 26/1/78
FLIGHT No - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 03
ELEVATION ANGLE - 4
RECEIVER 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
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET
78-17-B-14

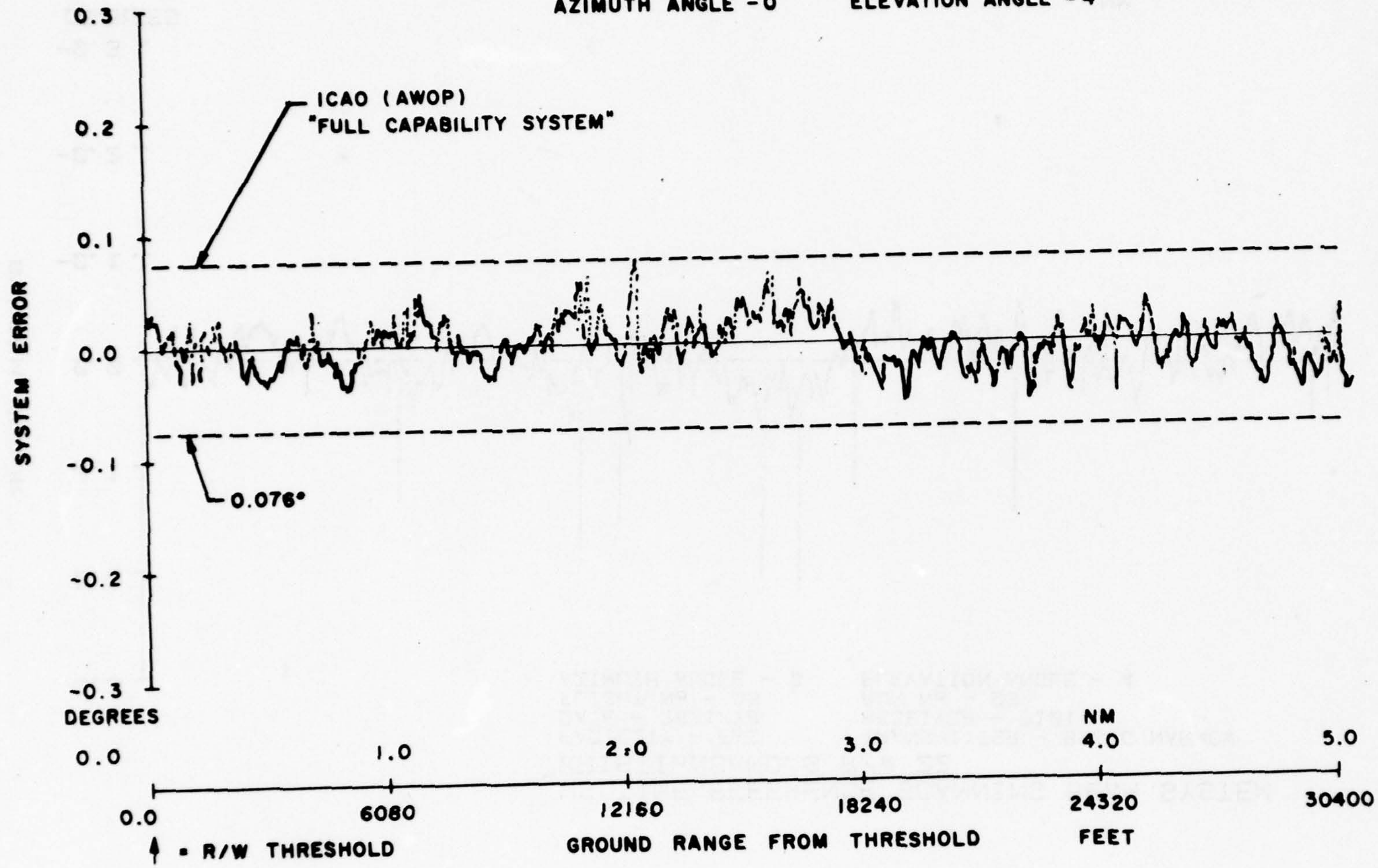

US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - FAZ
DATE - 25/1/78
FLIGHT No - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 03
ELEVATION ANGLE - 4
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
0
6080
12160
18240
24320
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD FEET

78-17-B-15

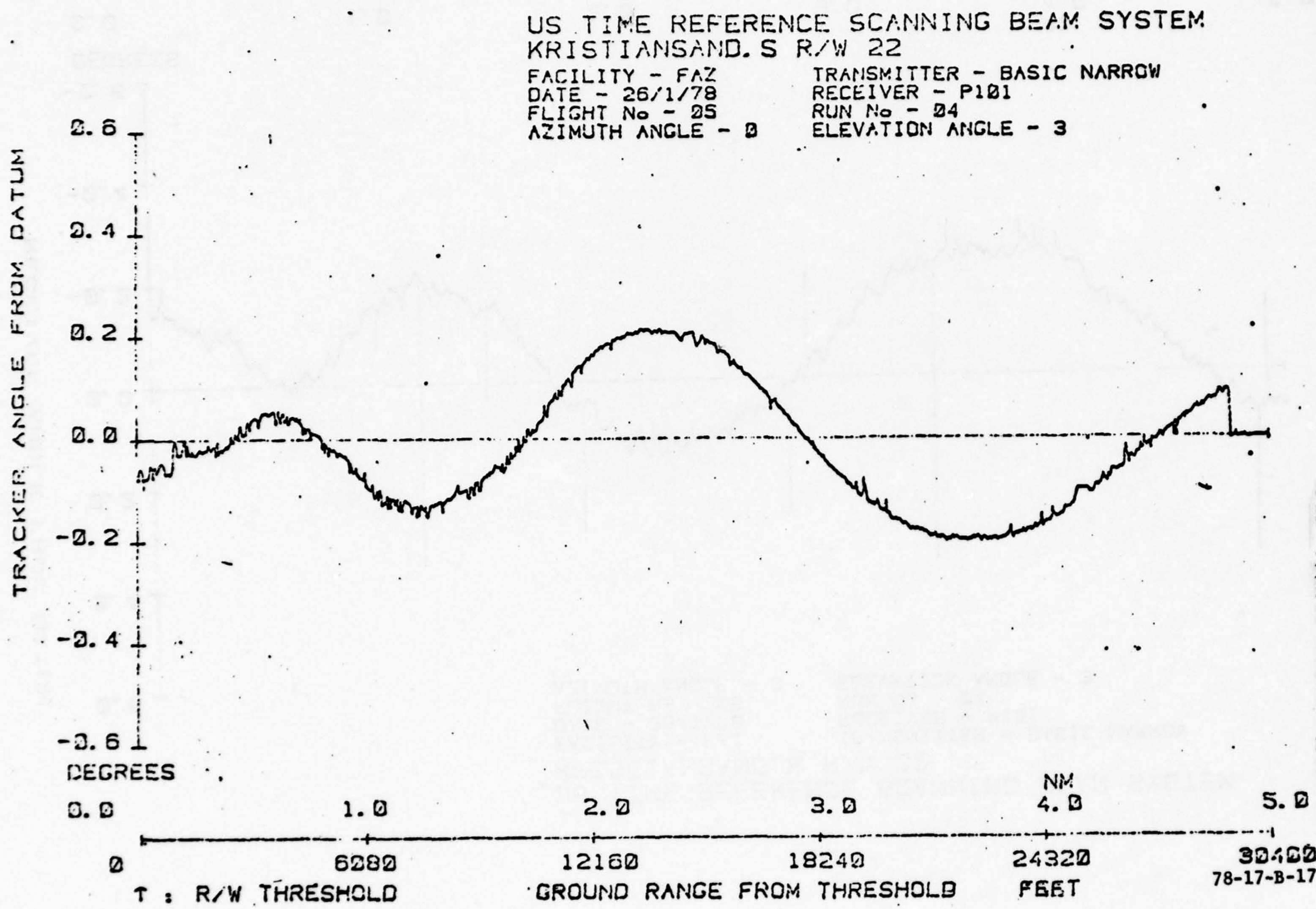
US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND.S R/W 22

FACILITY - FAZ
DATE - 26/1/78
FLIGHT NO. -05
AZIMUTH ANGLE -0

TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN NO. -03
ELEVATION ANGLE -4



78-17-B-16


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - FAZ
DATE - 26/1/78
FLIGHT No - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 04
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
NM
4.0
5.0
0
6080
12160
18240
24320
30400
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-17-B-17

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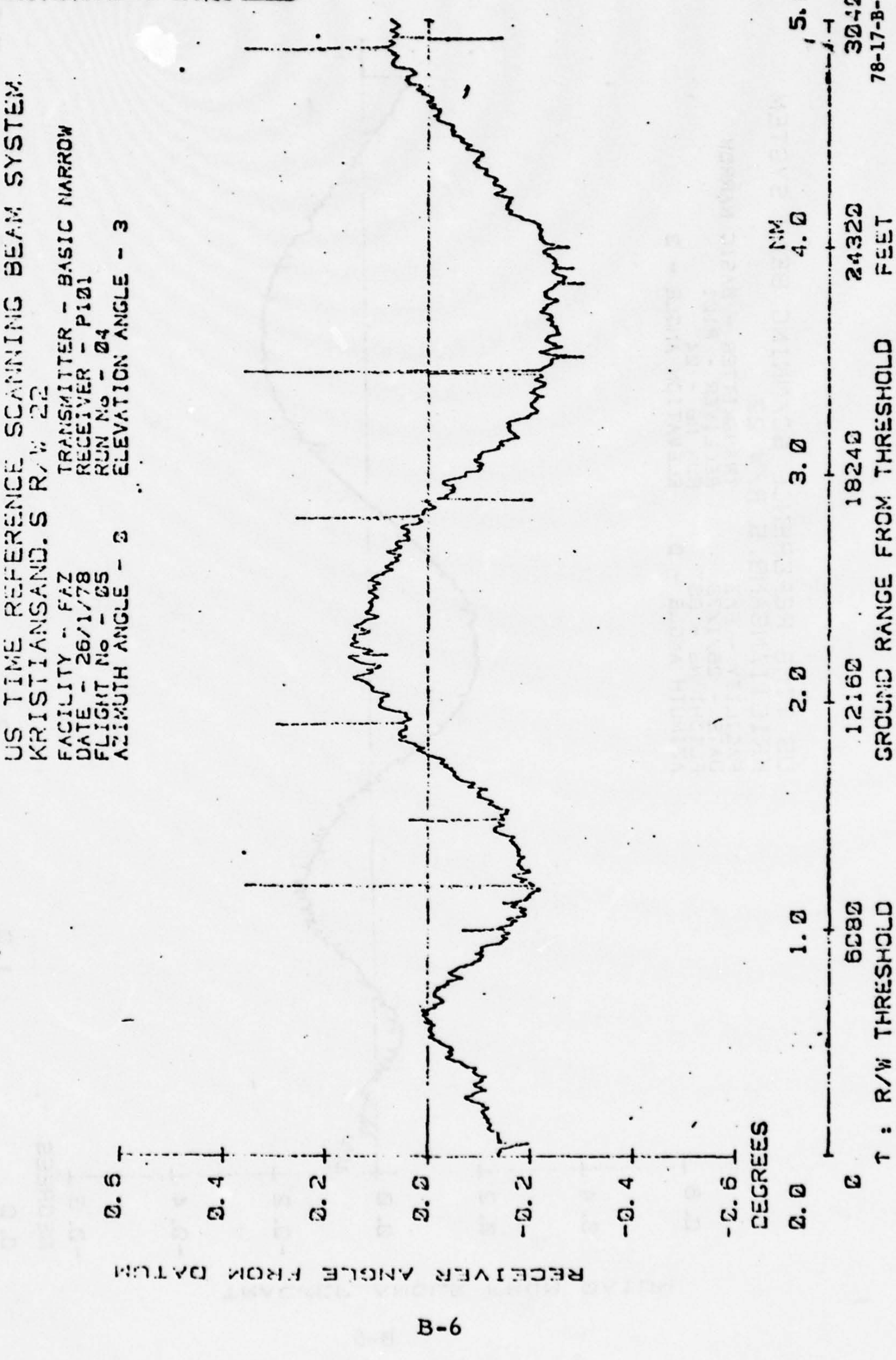
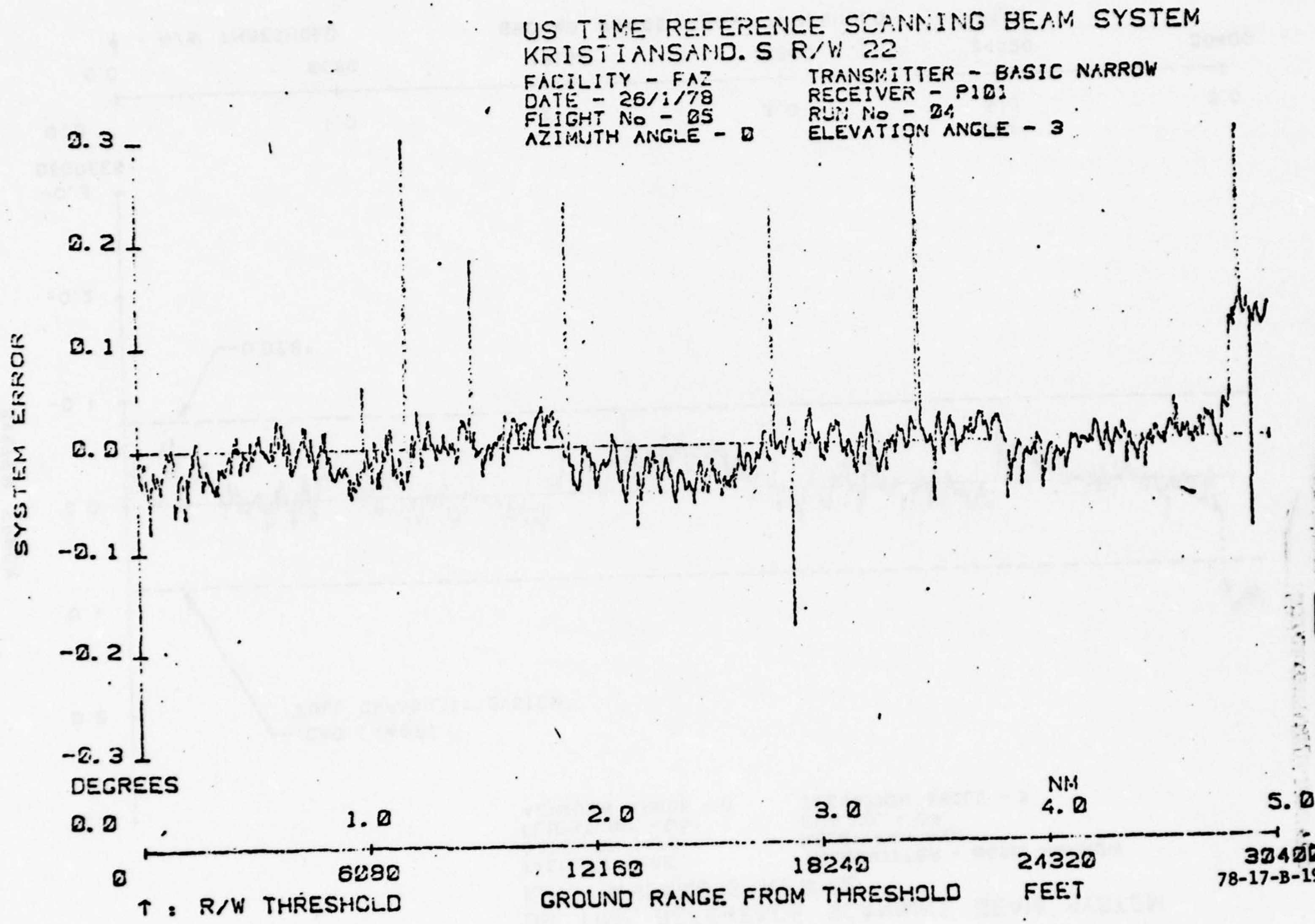
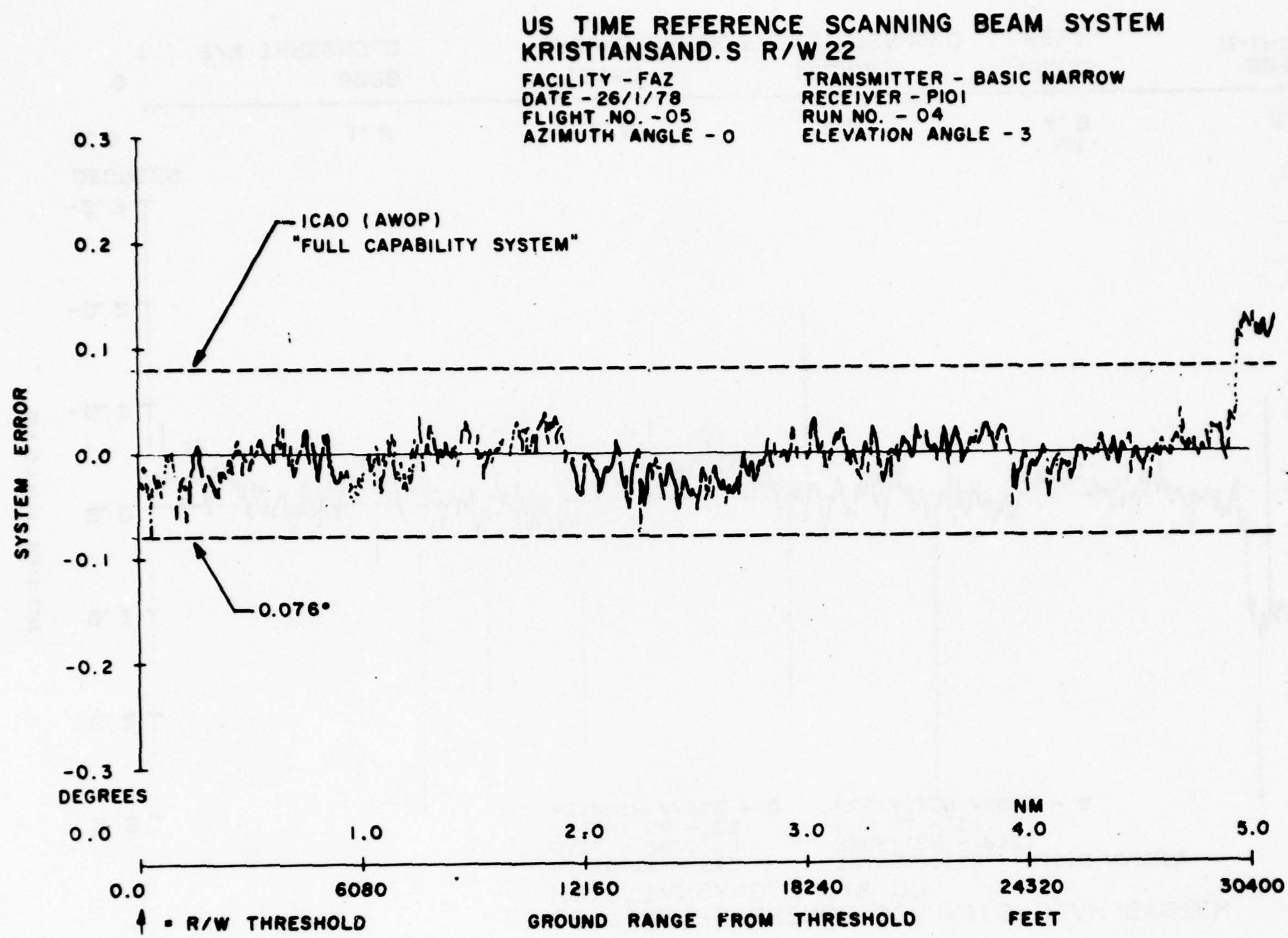
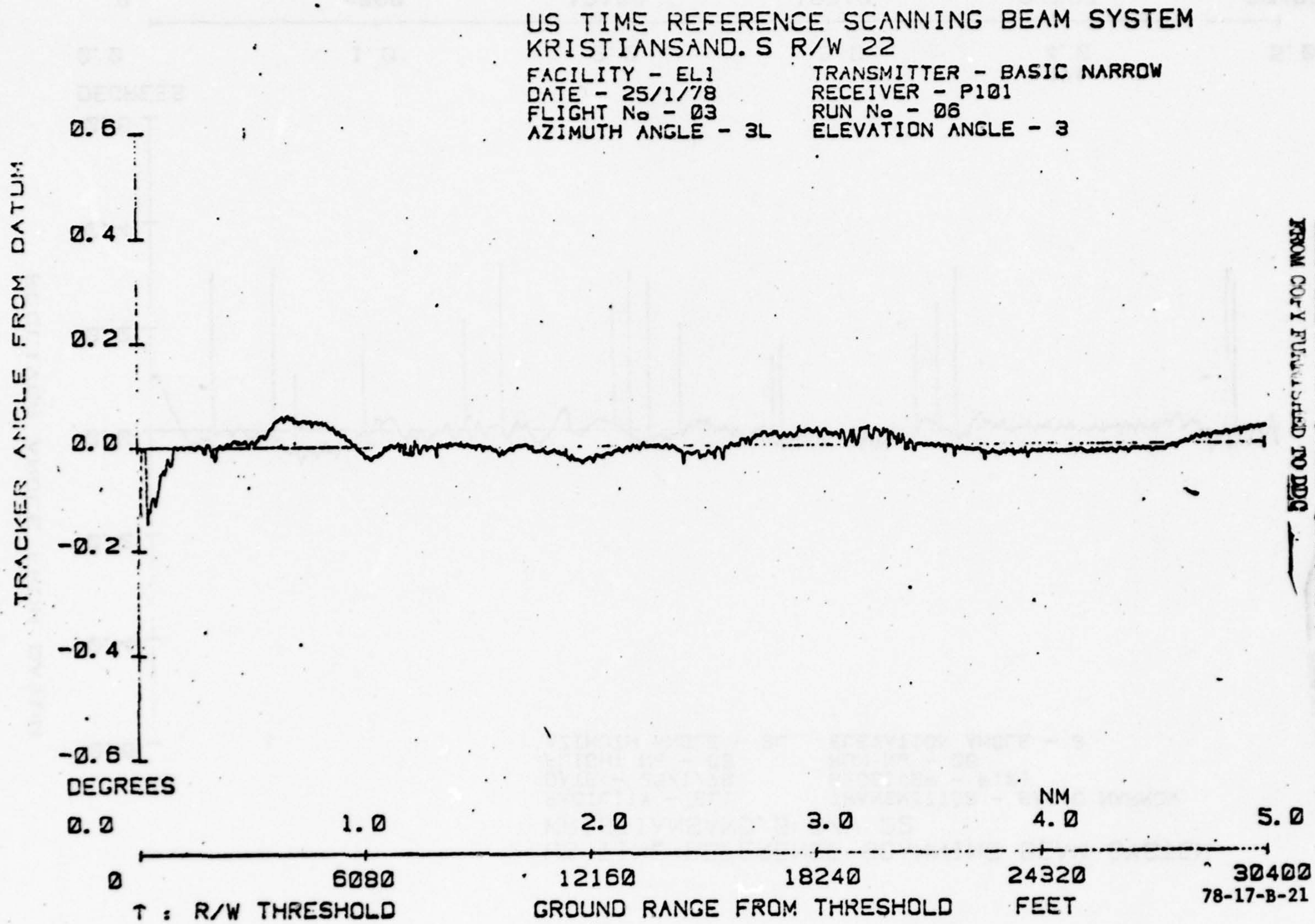
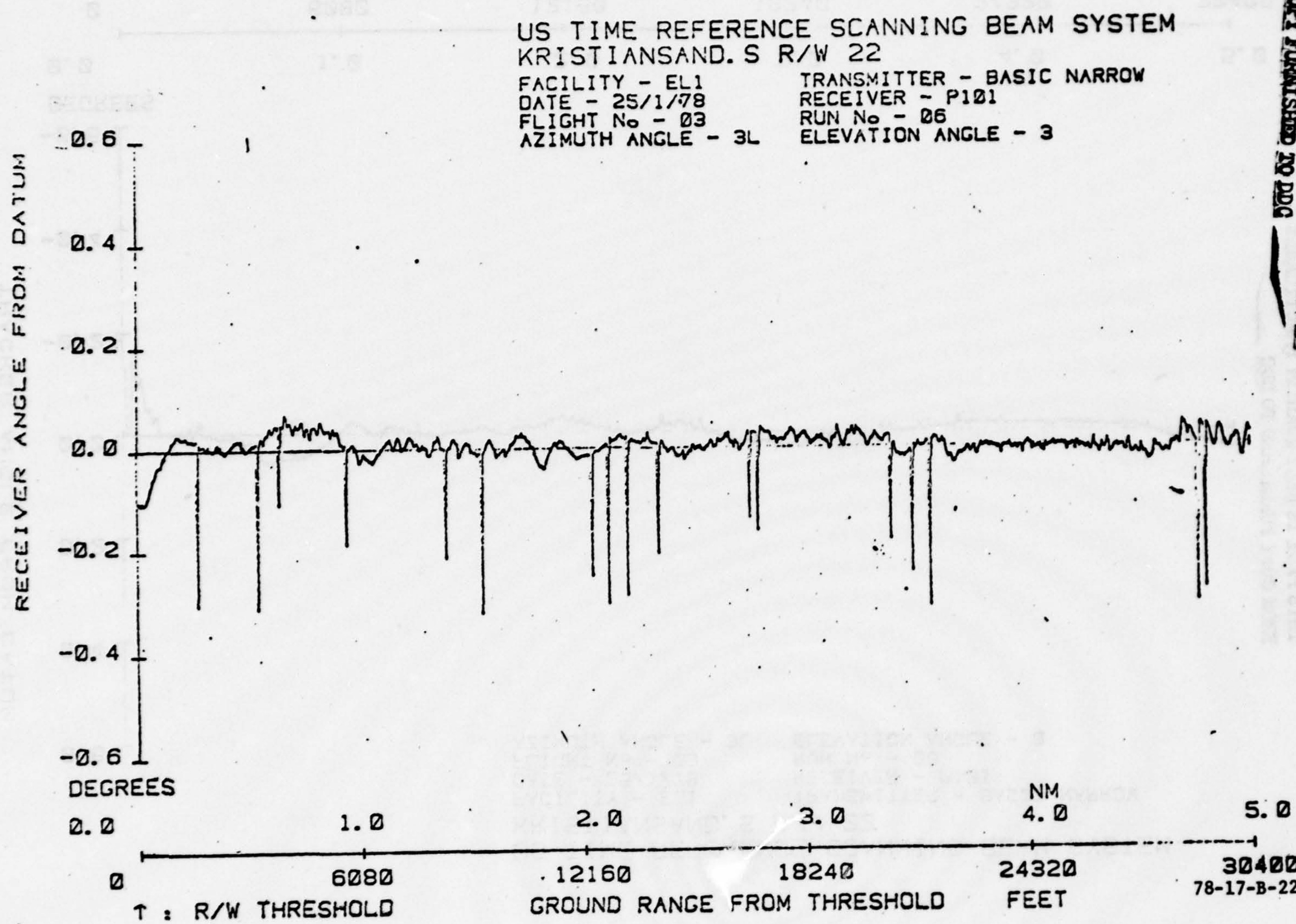


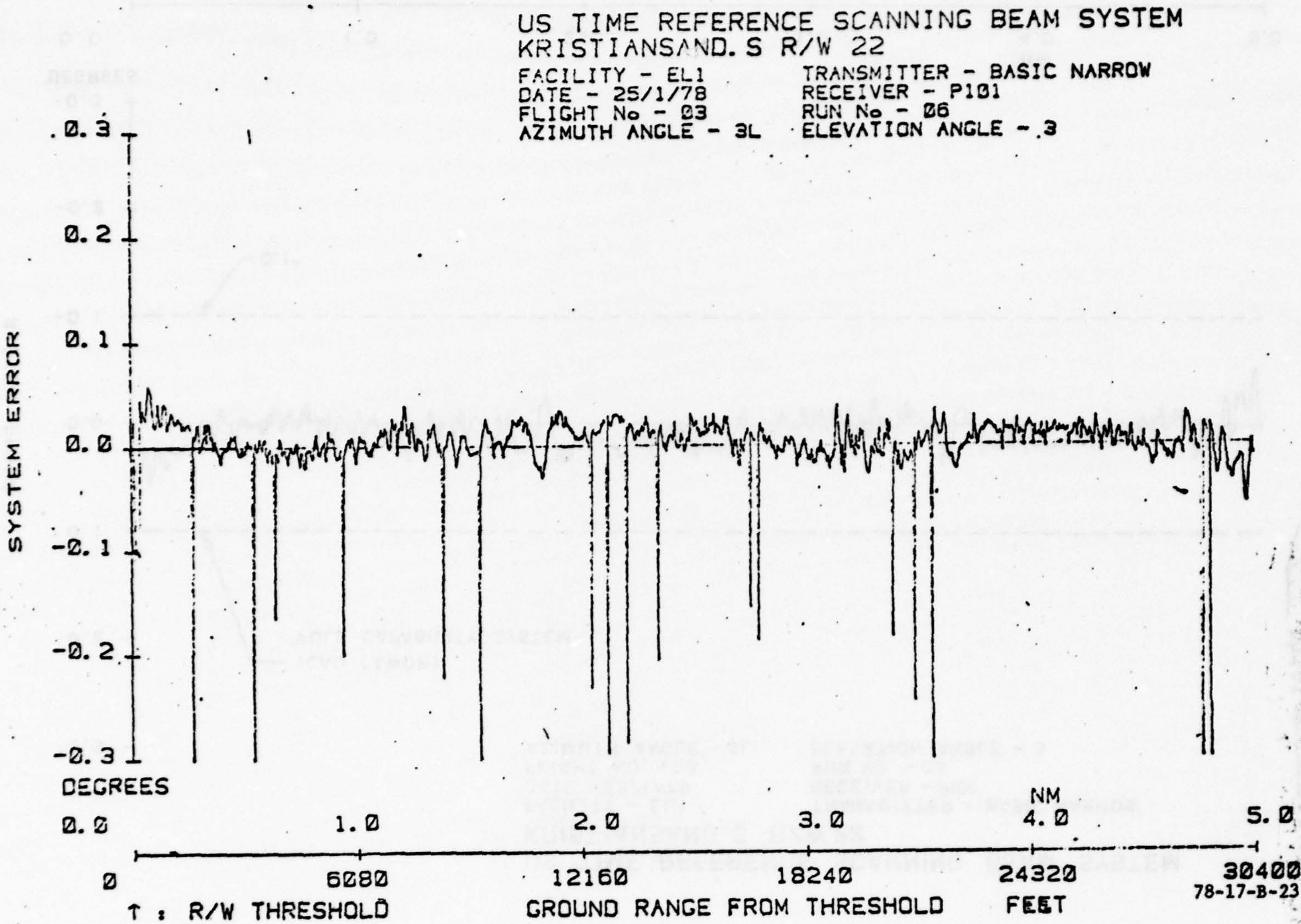

US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - FAZ
DATE - 26/1/78
FLIGHT No - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 04
ELEVATION ANGLE - 3
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
0.0
1.0
2.0
3.0
NM
4.0
5.0
0
6080
12160
18240
24320
30400
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-17-B-19

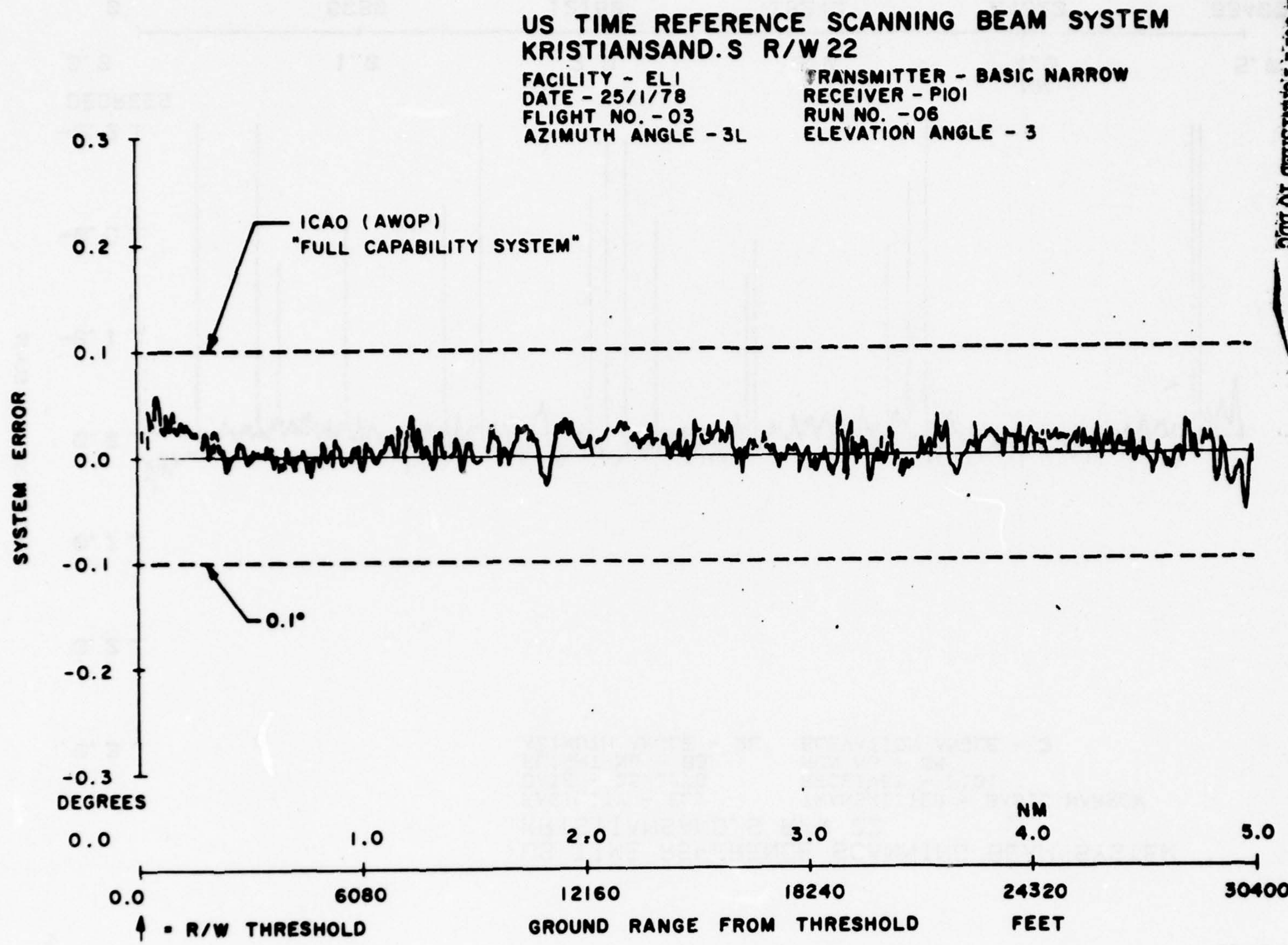

US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND.S R/W 22
FACILITY - FAZ
DATE - 26/1/78
FLIGHT NO. - 05
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - PIOI
RUN NO. - 04
ELEVATION ANGLE - 3
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
0.076°
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
NM
0.0
1.0
2.0
3.0
4.0
5.0
0.0
6080
12160
18240
24320
30400
= R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET

78-17-B-20


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - EL1
DATE - 25/1/78
FLIGHT No - 03
AZIMUTH ANGLE - 3L
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 06
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
5.0
NM
0
6080
12160
18240
24320
30400
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-17-B-21


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - EL1
DATE - 25/1/78
FLIGHT No - 03
AZIMUTH ANGLE - 3L
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 06
ELEVATION ANGLE - 3
RECEIVER ANGLE FROM DATUM
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
DEGREES
0.0
1.0
2.0
3.0
NM
4.0
5.0
0
6080
12160
18240
24320
30400
T : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET
78-17-B-22


US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - EL1
DATE - 25/1/78
FLIGHT No - 03
AZIMUTH ANGLE - 3L
TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 06
ELEVATION ANGLE - .3
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
NM
0
6080
12160
18240
24320
30400
78-17-B-23
↑ : R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET

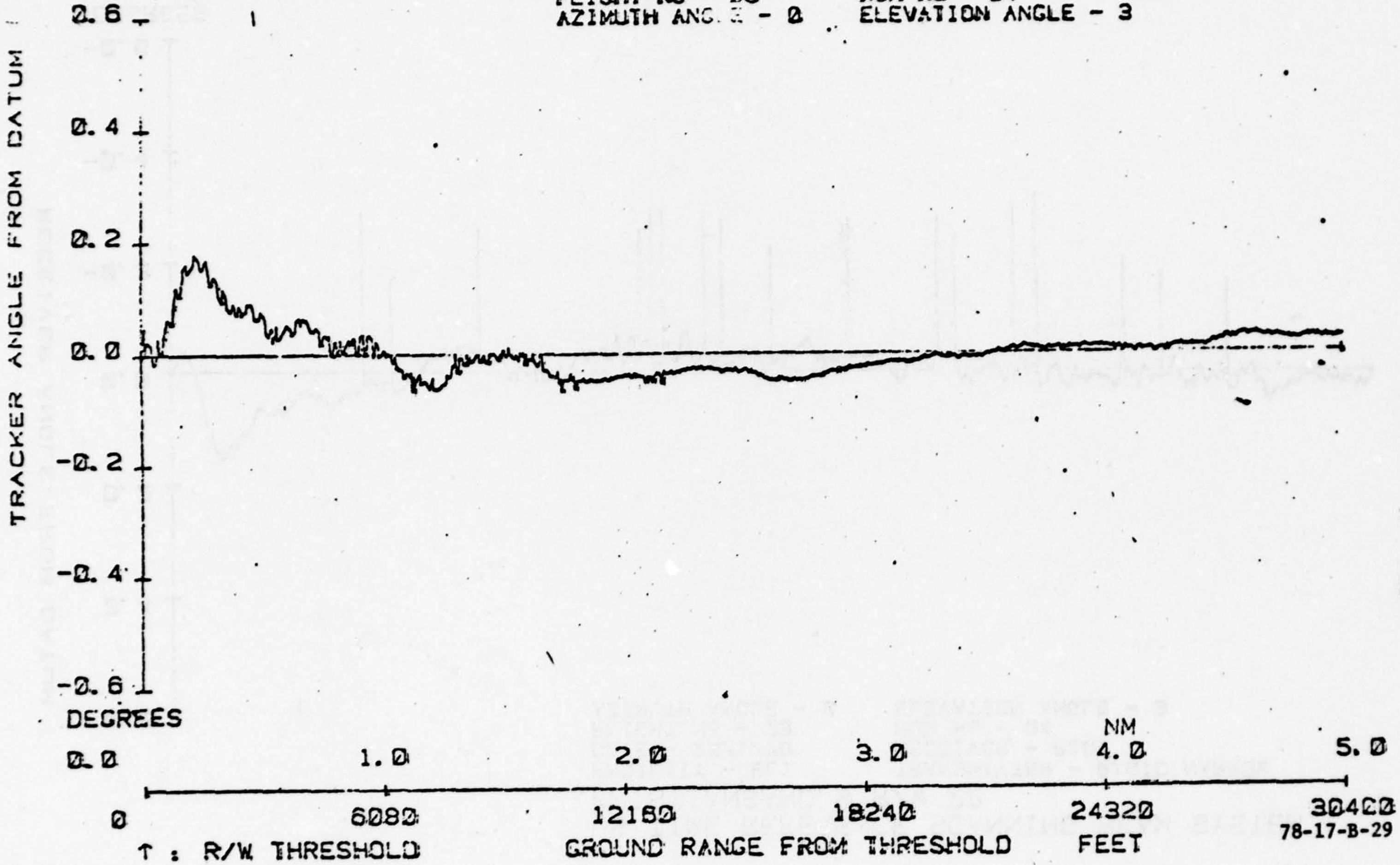

US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22
FACILITY - ELI
DATE - 25/1/78
FLIGHT NO. - 03
AZIMUTH ANGLE - 3L
TRANSMITTER - BASIC NARROW
RECEIVER - PIOI
RUN NO. - 06
ELEVATION ANGLE - 3
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
0.1°
SYSTEM ERROR
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
0.0
1.0
2.0
3.0
4.0
5.0
NM
0.0
6080
12160
18240
24320
30400
= R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
FEET

78-17-B-24

US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND. S R/W 22

FACILITY - EL1
DATE - 25/1/78
FLIGHT No - 23
AZIMUTH ANGLE - 0

TRANSMITTER - BASIC NARROW
RECEIVER - P101
RUN No - 04
ELEVATION ANGLE - 3



78-17-B-29

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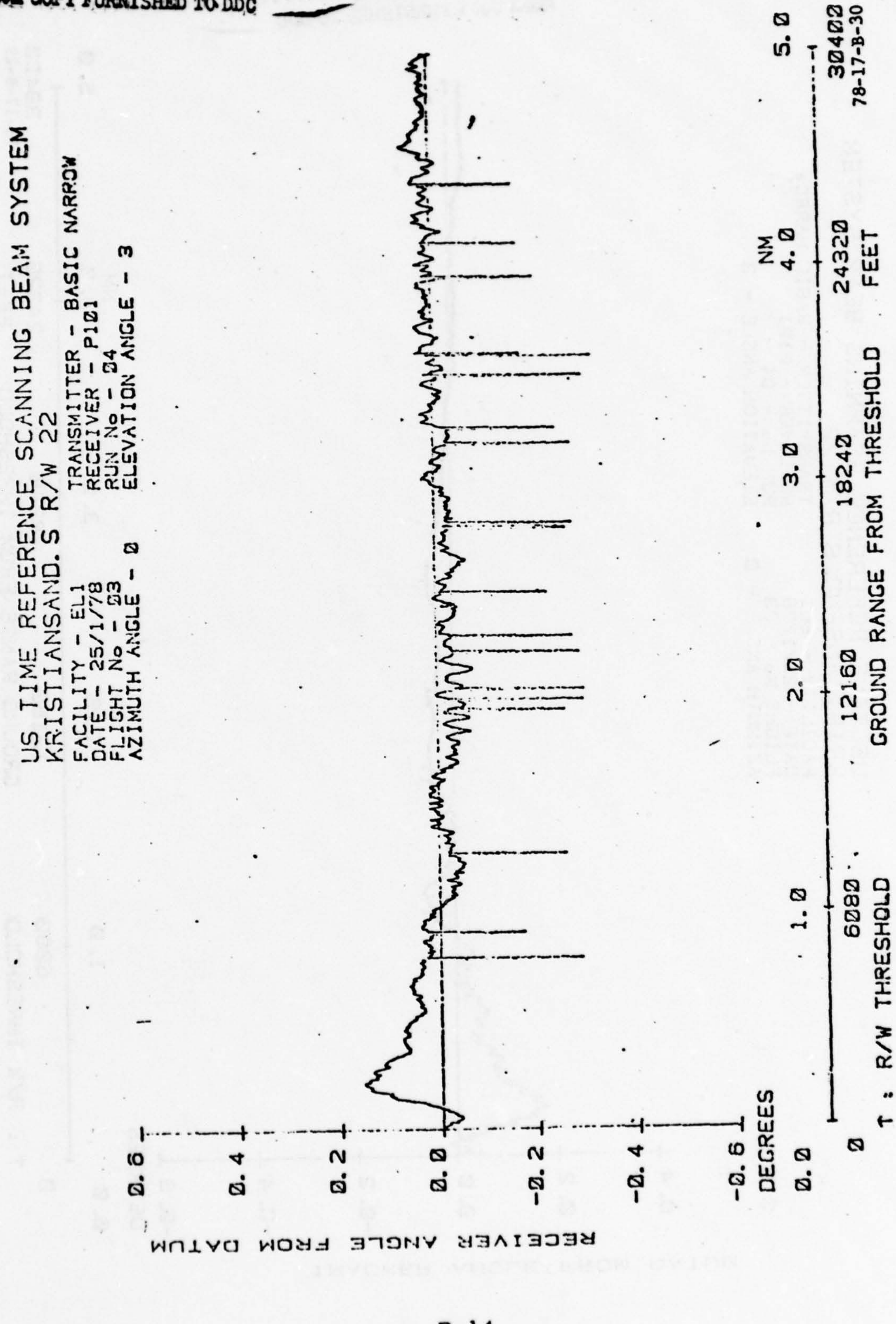

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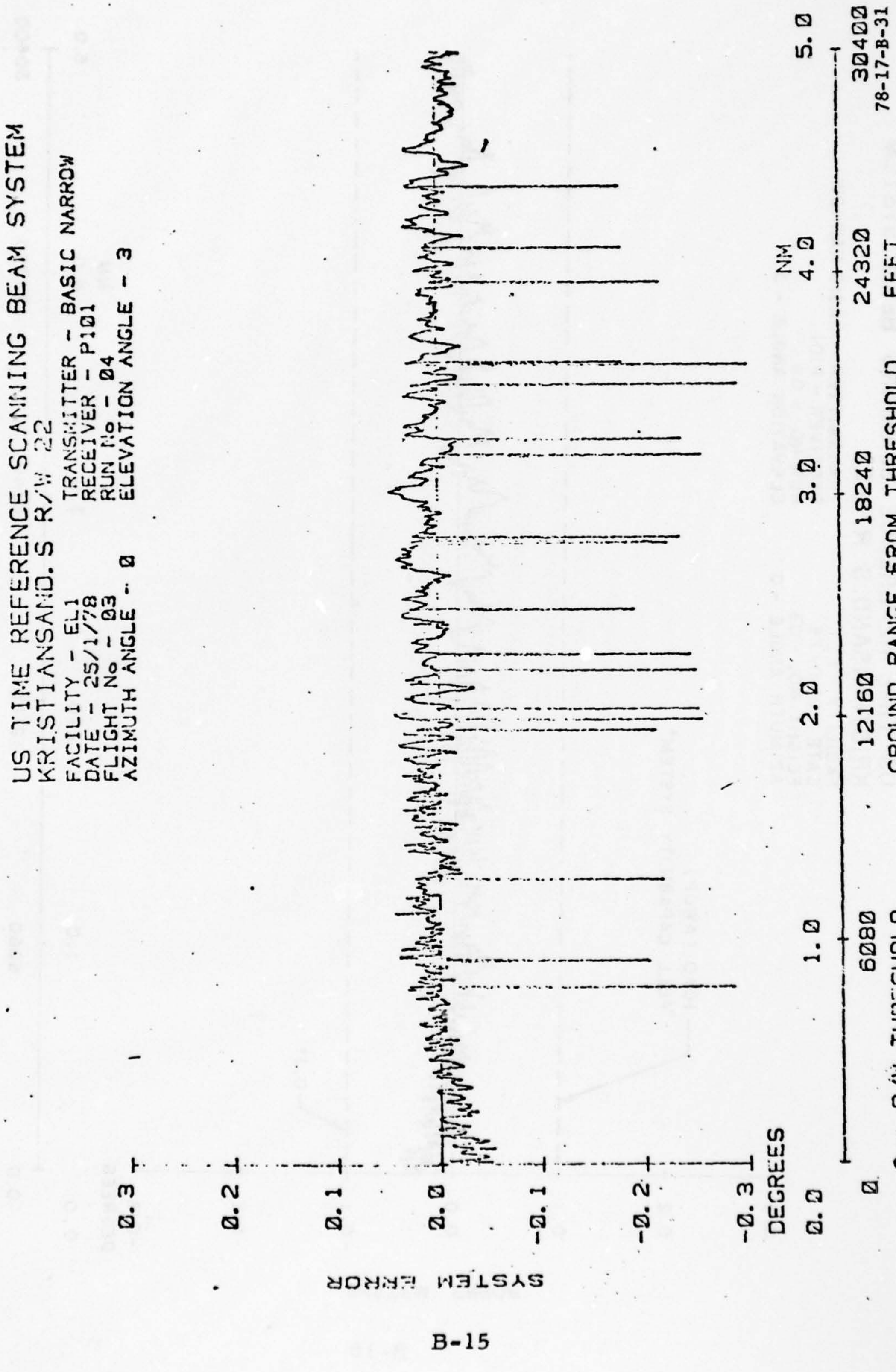
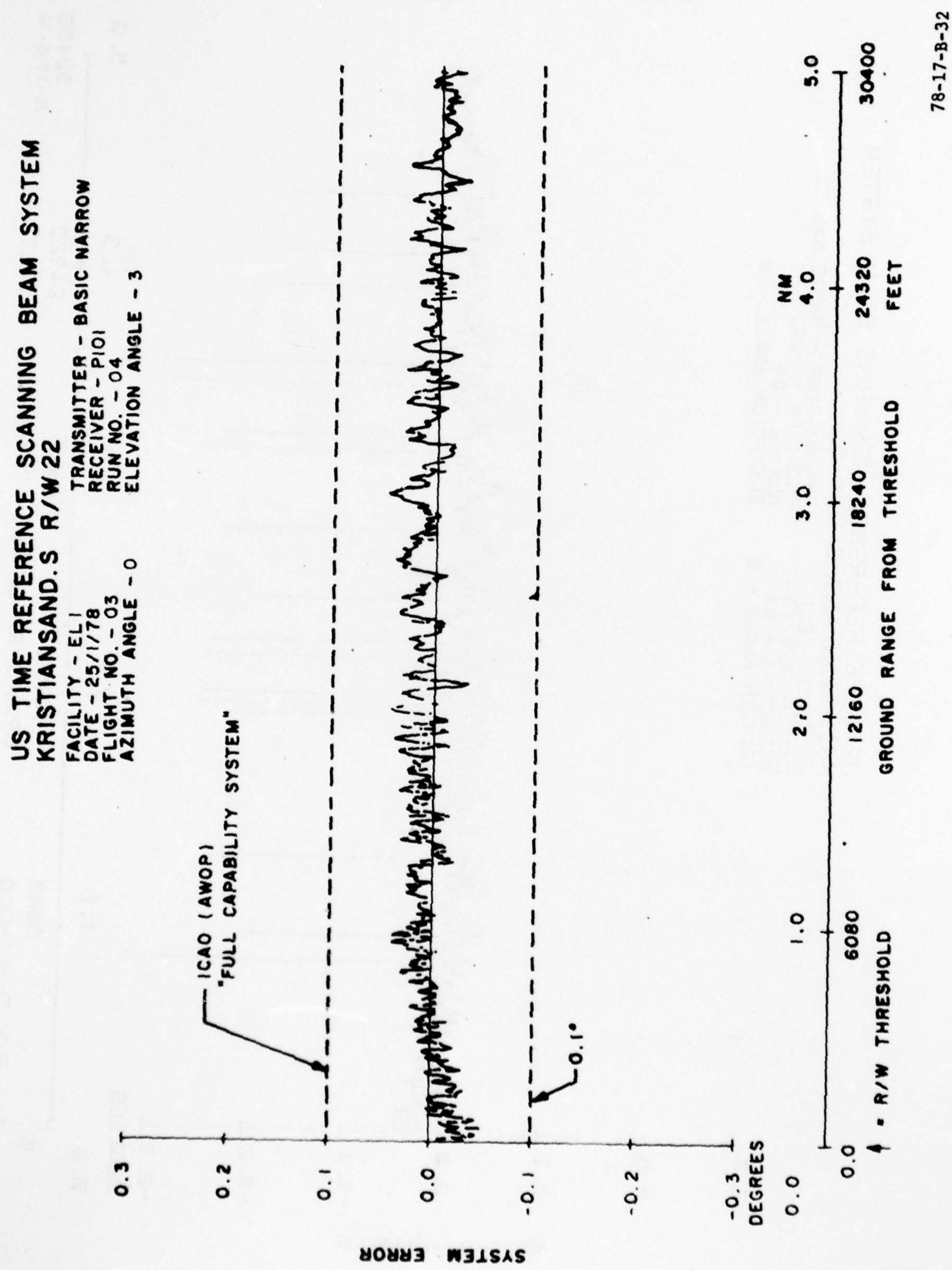



US TIME REFERENCE SCANNING BEAM SYSTEM
KRISTIANSAND.S R/W 22
FACILITY - ELI
DATE - 25/1/78
FLIGHT NO. - 03
AZIMUTH ANGLE - 0
TRANSMITTER - BASIC NARROW
RECEIVER - PIOI
RUN NO. - 04
ELEVATION ANGLE - 3
ICAO (AWOP)
"FULL CAPABILITY SYSTEM"
0.1°
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
DEGREES
SYSTEM ERROR
0.0
1.0
2.0
3.0
4.0
5.0
NM
6080
12160
18240
24320
30400
FEET
R/W THRESHOLD
GROUND RANGE FROM THRESHOLD
78-17-B-32

APPENDIX C

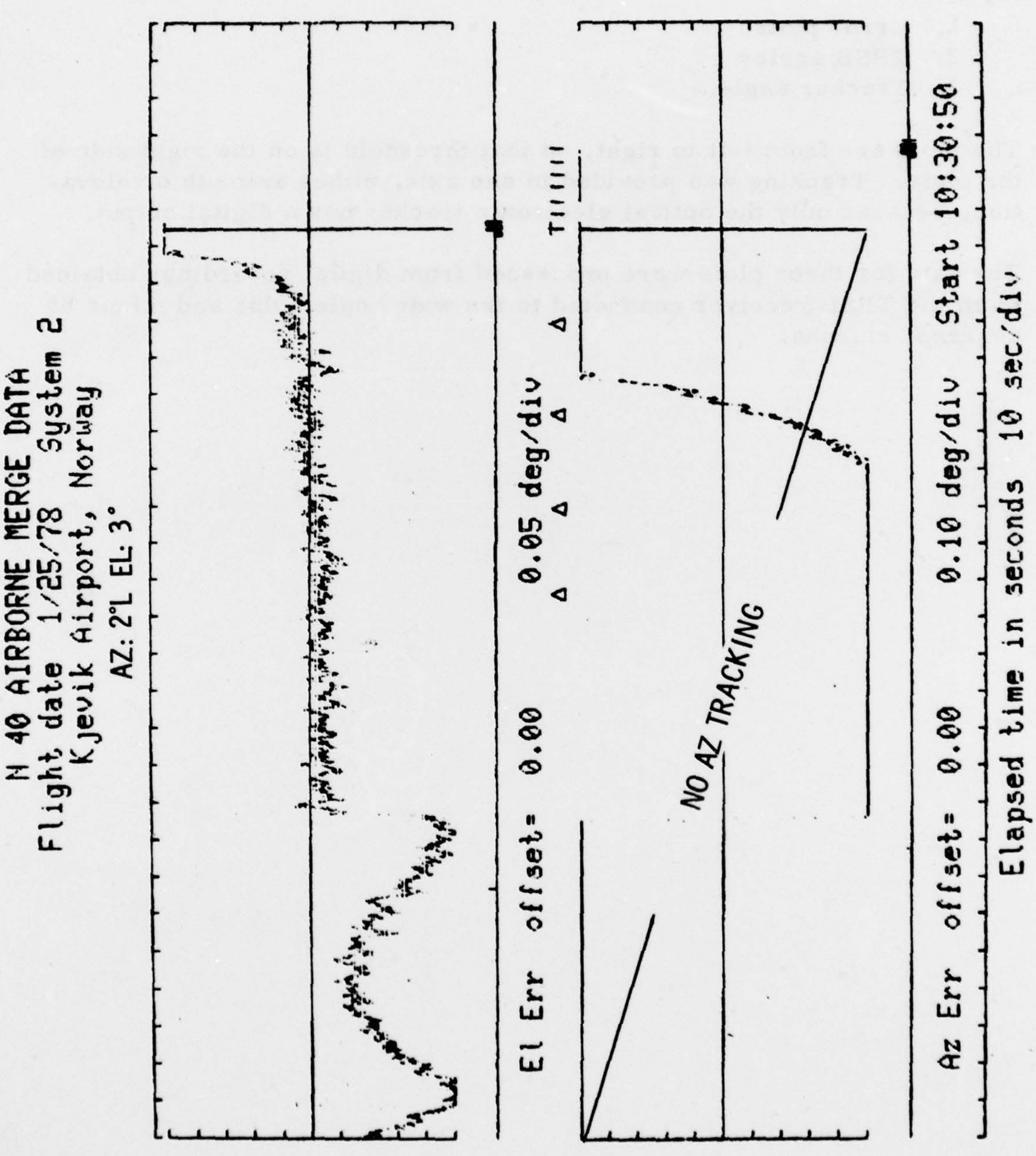
U.S. DIGITAL TRSB DATA

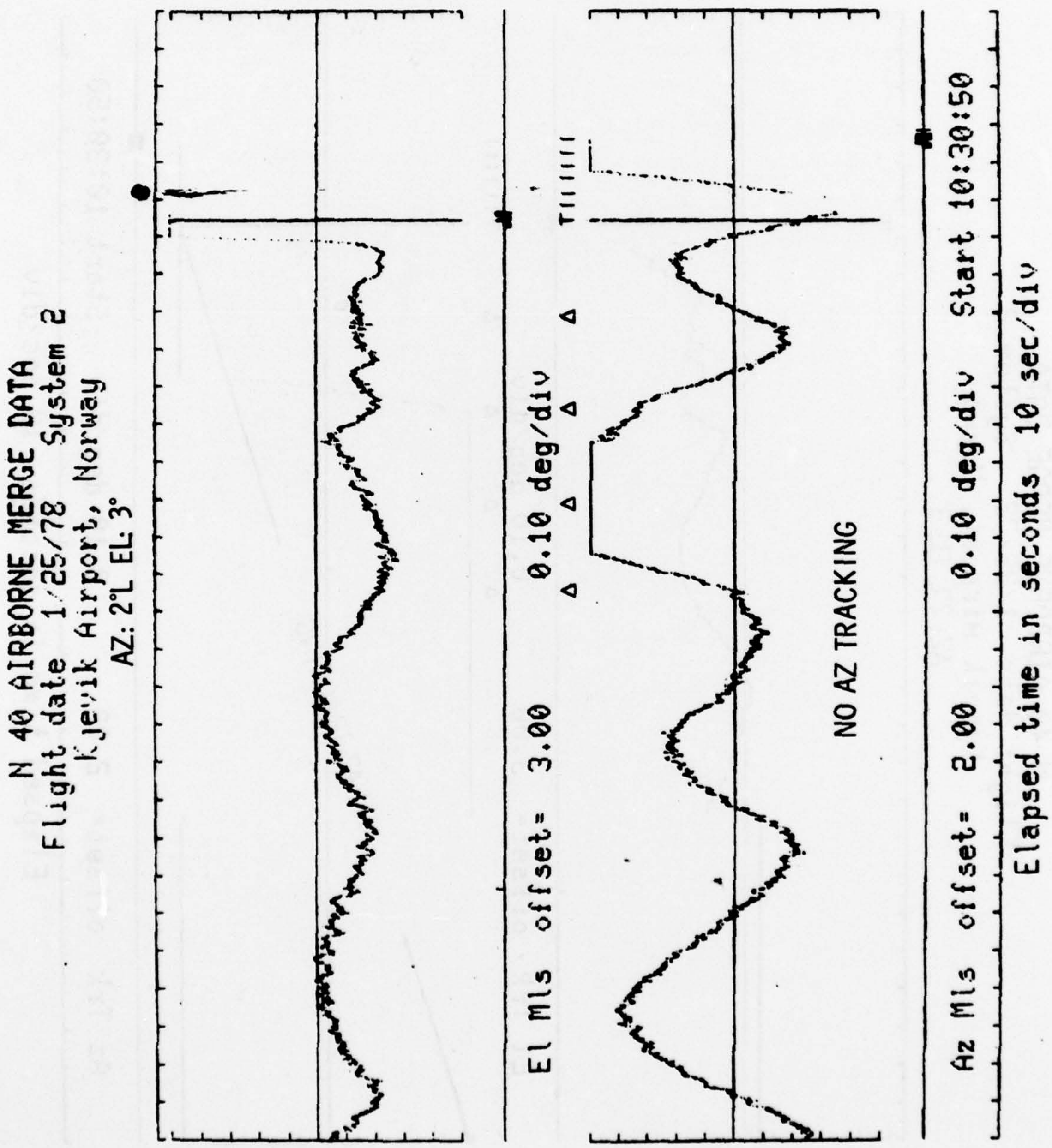
The plots in this Appendix are presented in groups of three pages representing one run, as identified by a common start time, and are arranged in the following order:

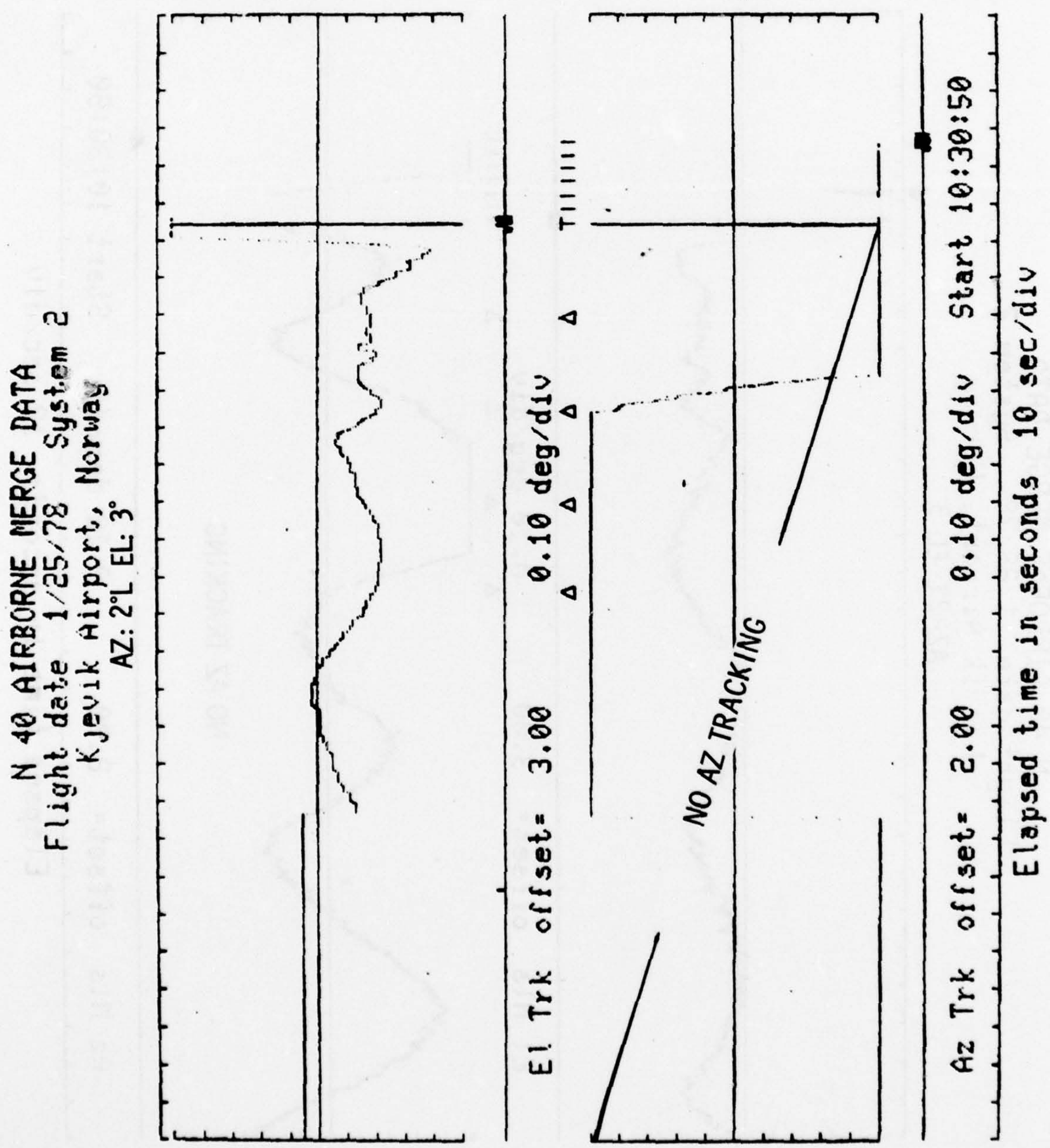
1. Error plots
2. TRSB angles
3. Tracker angle

The plots are from left to right, so that threshold is on the right side of the plots. Tracking was provided in one axis, either azimuth or elevation, because only the optical electronic tracker has a digital output.

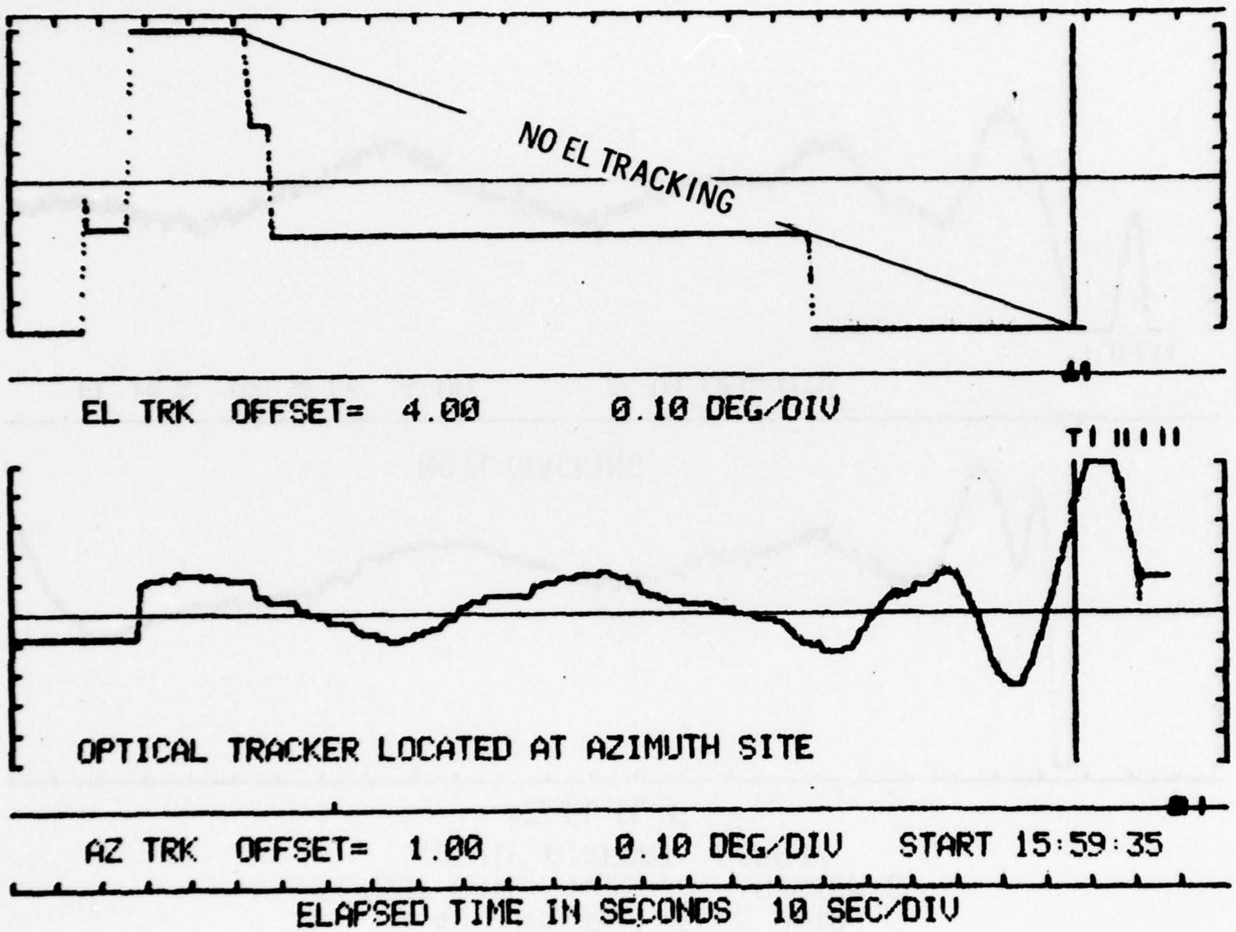
The data for these plots were processed from digital recordings obtained from the TRSB receiver connected to the wide angle, plus and minus 85 degrees, antenna.

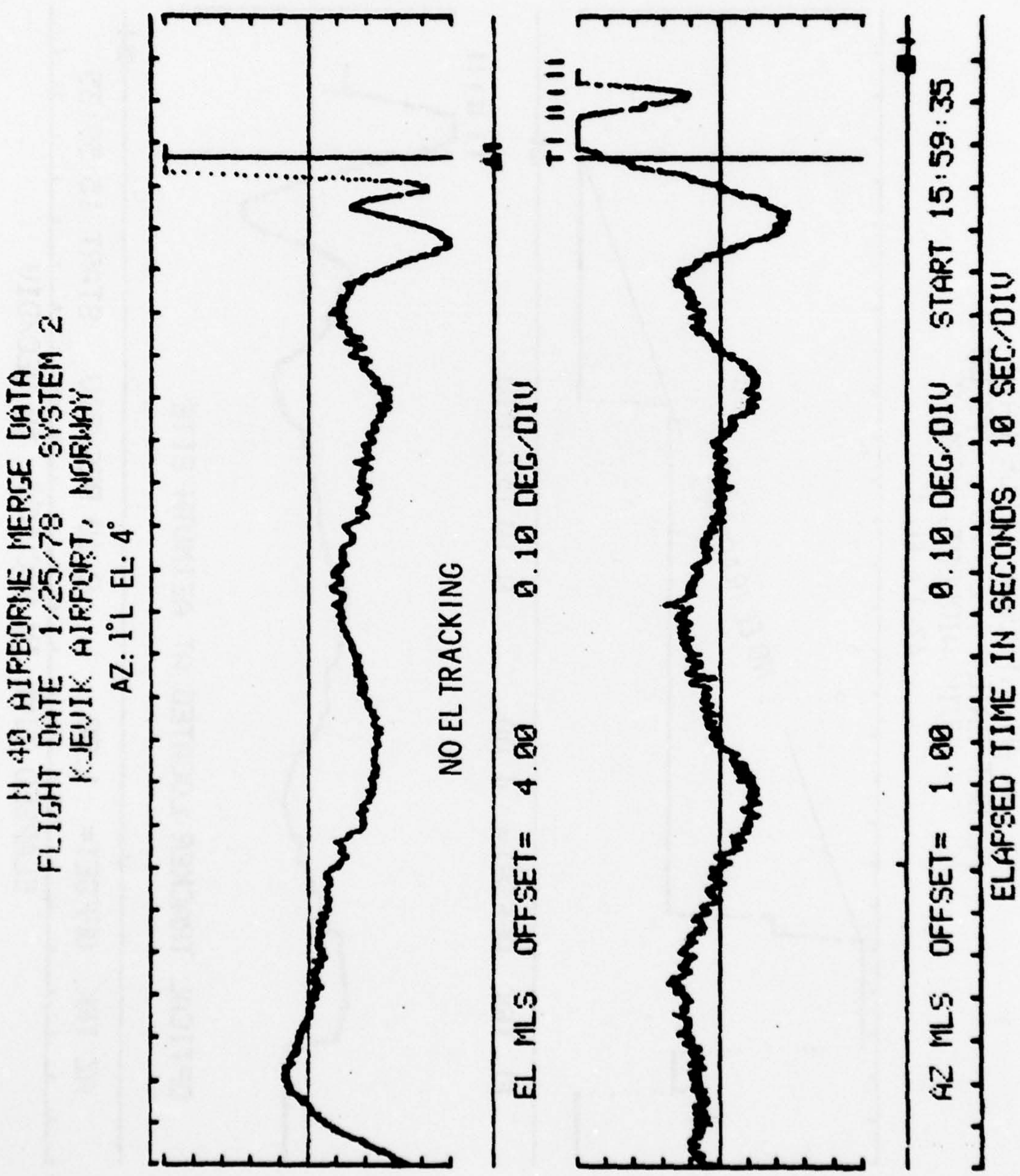

N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 2°L EL: 3°
El Err offset= 0.00 0.05 deg/div
NO AZ TRACKING
Az Err offset= 0.00 0.10 deg/div Start 10:30:50
Elapsed time in seconds 10 sec/div

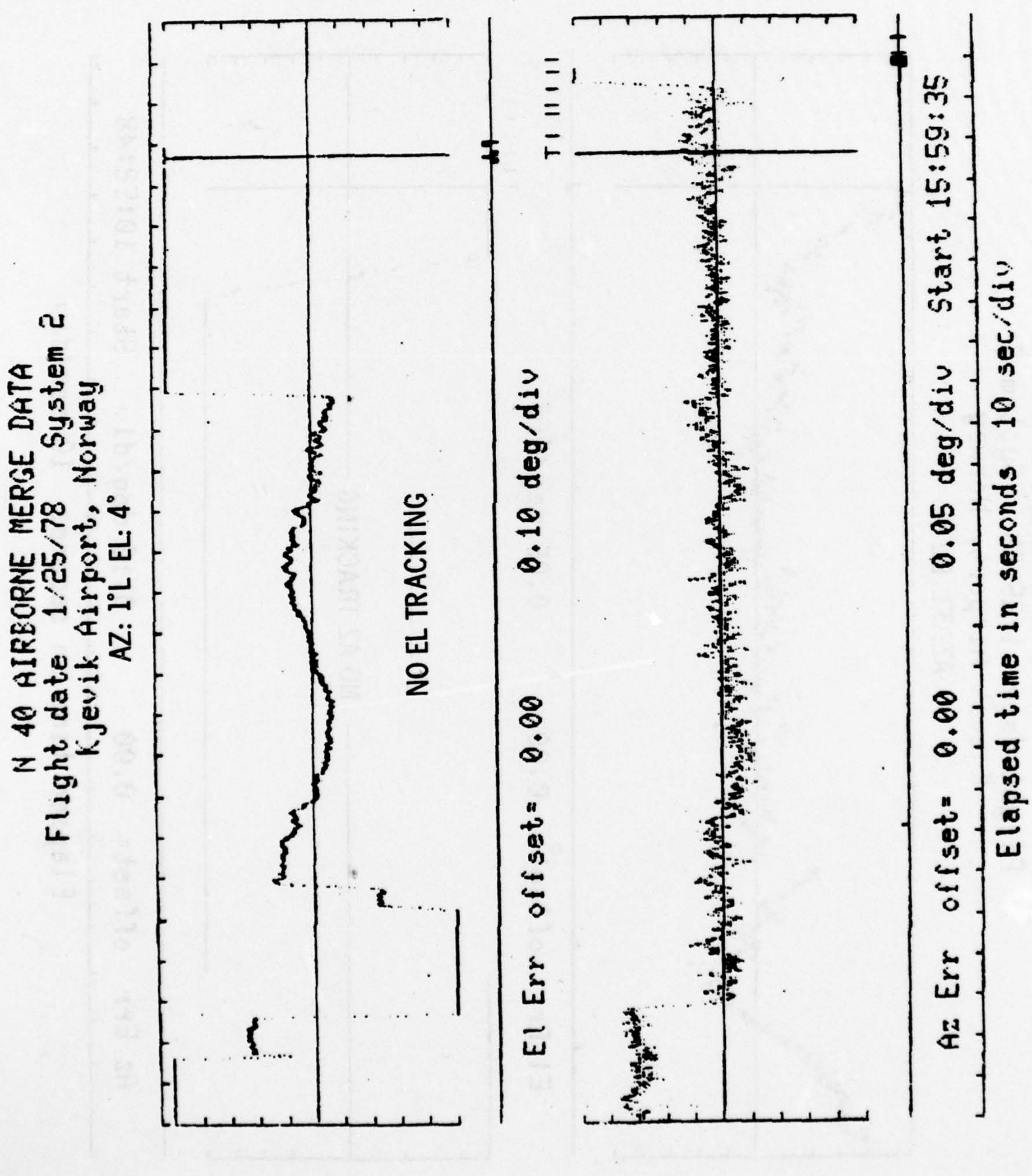

N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 2°L EL: 3°
El Mls offset= 3.00 0.10 deg/div
NO AZ TRACKING
Az Mls offset= 2.00 0.10 deg/div Start 10:30:50
Elapsed time in seconds 10 sec/div

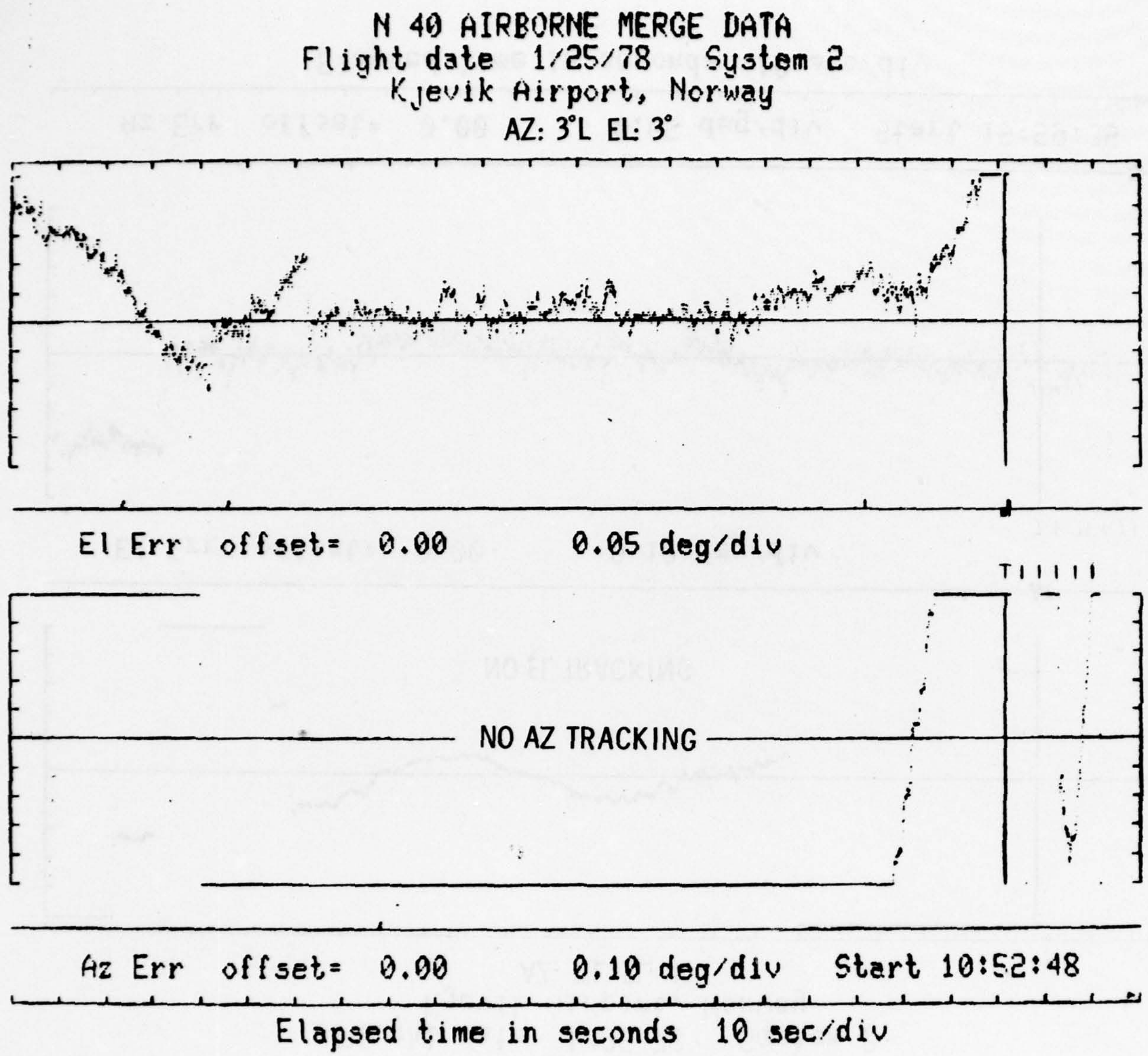

N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 2°L EL: 3°
El Trk offset= 3.00
0.10 deg/div
NO AZ TRACKING
Az Trk offset= 2.00
0.10 deg/div
Start 10:30:50
Elapsed time in seconds 10 sec/div

N 40 AIRBORNE MERGE DATA
FLIGHT DATE 1/25/78 SYSTEM 2
KJEVIK AIRPORT, NORWAY
AZ: 1°L EL: 4°




N 40 AIRBORNE MERGE DATA
FLIGHT DATE 1/25/78 SYSTEM 2
KJEVIK AIRPORT, NORWAY
AZ: 1°L EL: 4°
NO EL TRACKING
EL MLS OFFSET= 4.00 0.10 DEG/DIV
AZ MLS OFFSET= 1.00 0.10 DEG/DIV START 15:59:35
ELAPSED TIME IN SECONDS 10 SEC/DIV


N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 1°L EL: 4°
NO EL TRACKING
El Err offset= 0.00 0.10 deg/div
Az Err offset= 0.00 0.05 deg/div Start 15:59:35
Elapsed time in seconds 10 sec/div



N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 3°L EL: 3°
El Err offset= 0.00 0.05 deg/div
NO AZ TRACKING
Az Err offset= 0.00 0.10 deg/div Start 10:52:48
Elapsed time in seconds 10 sec/div

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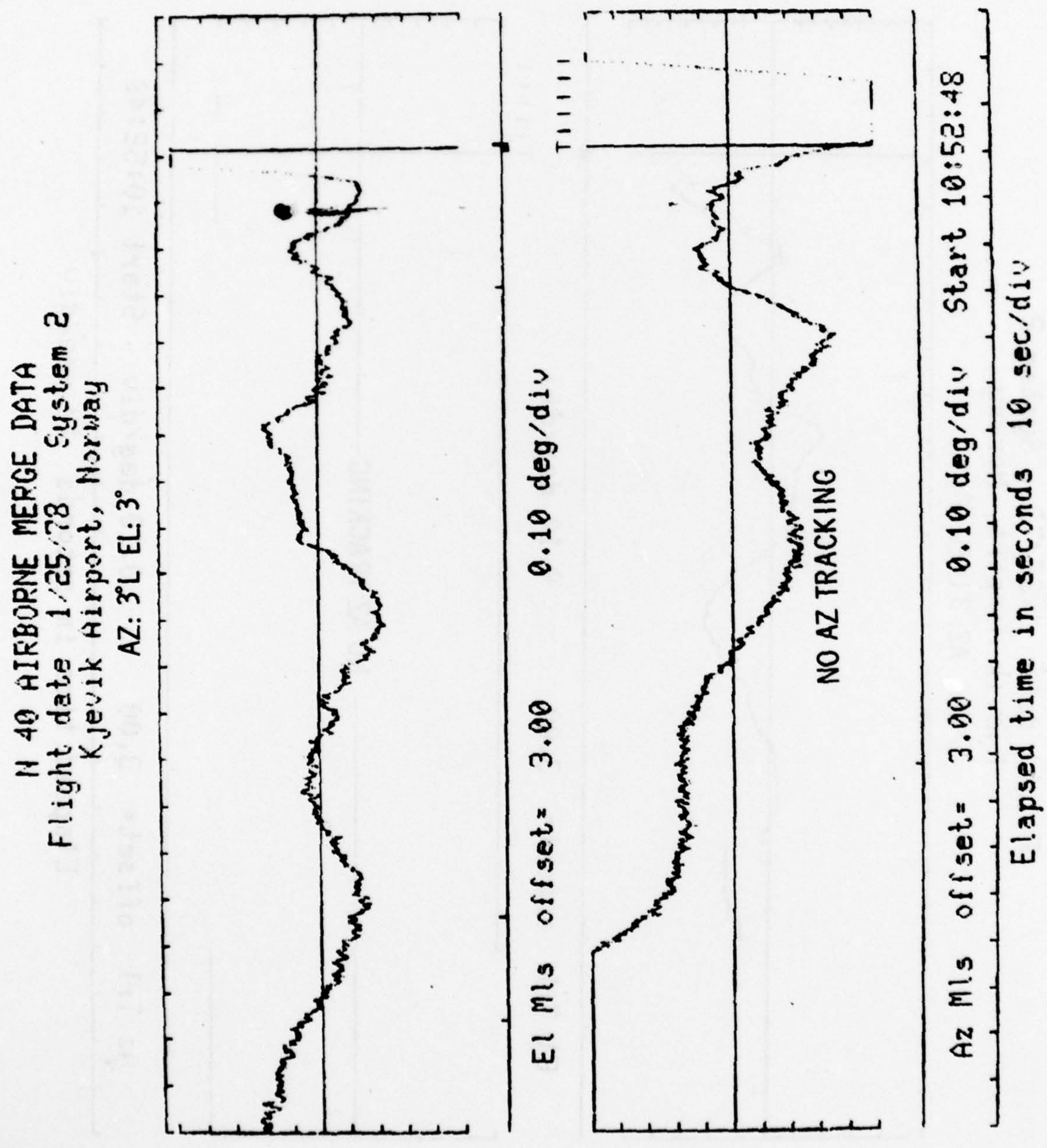
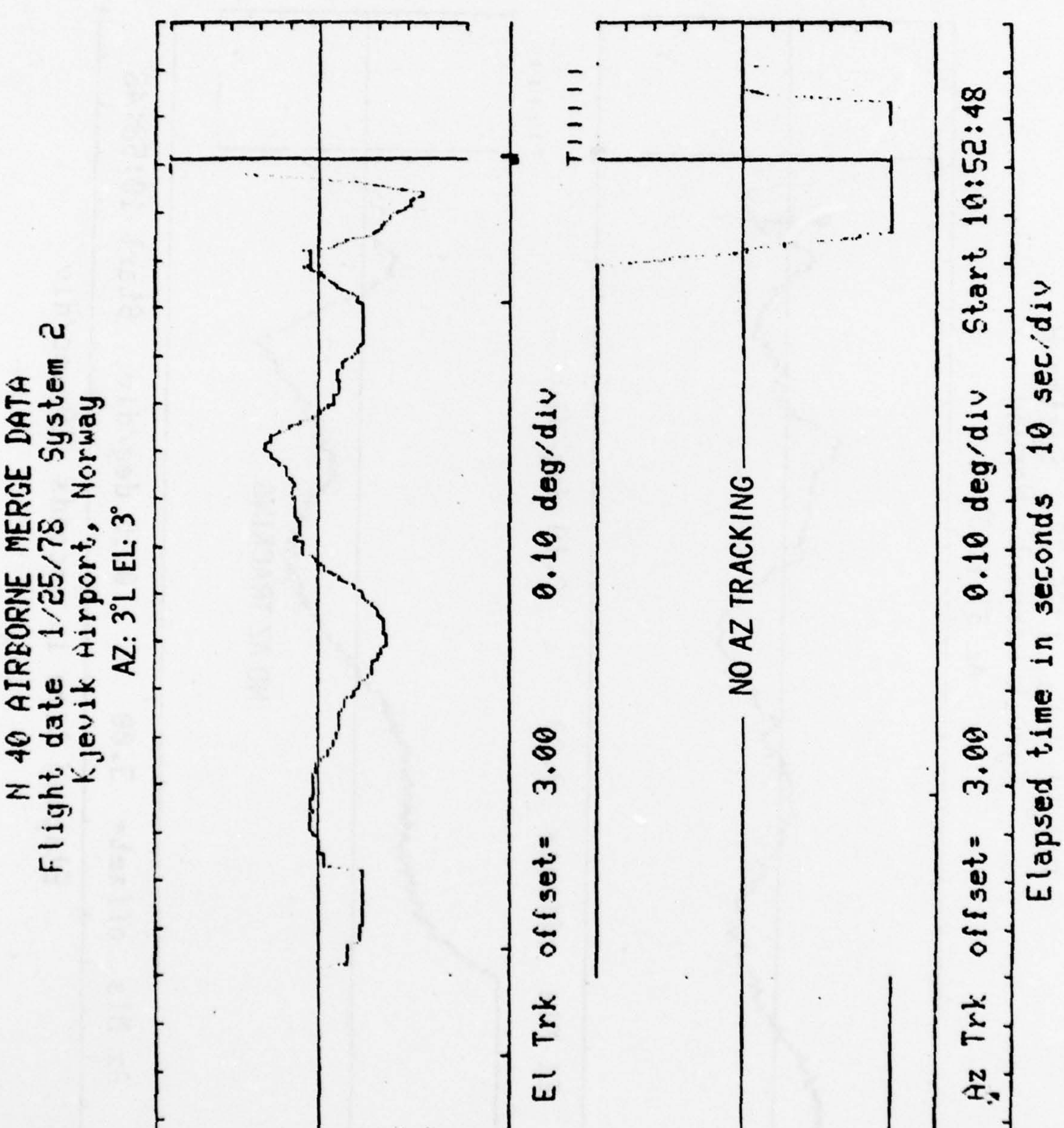
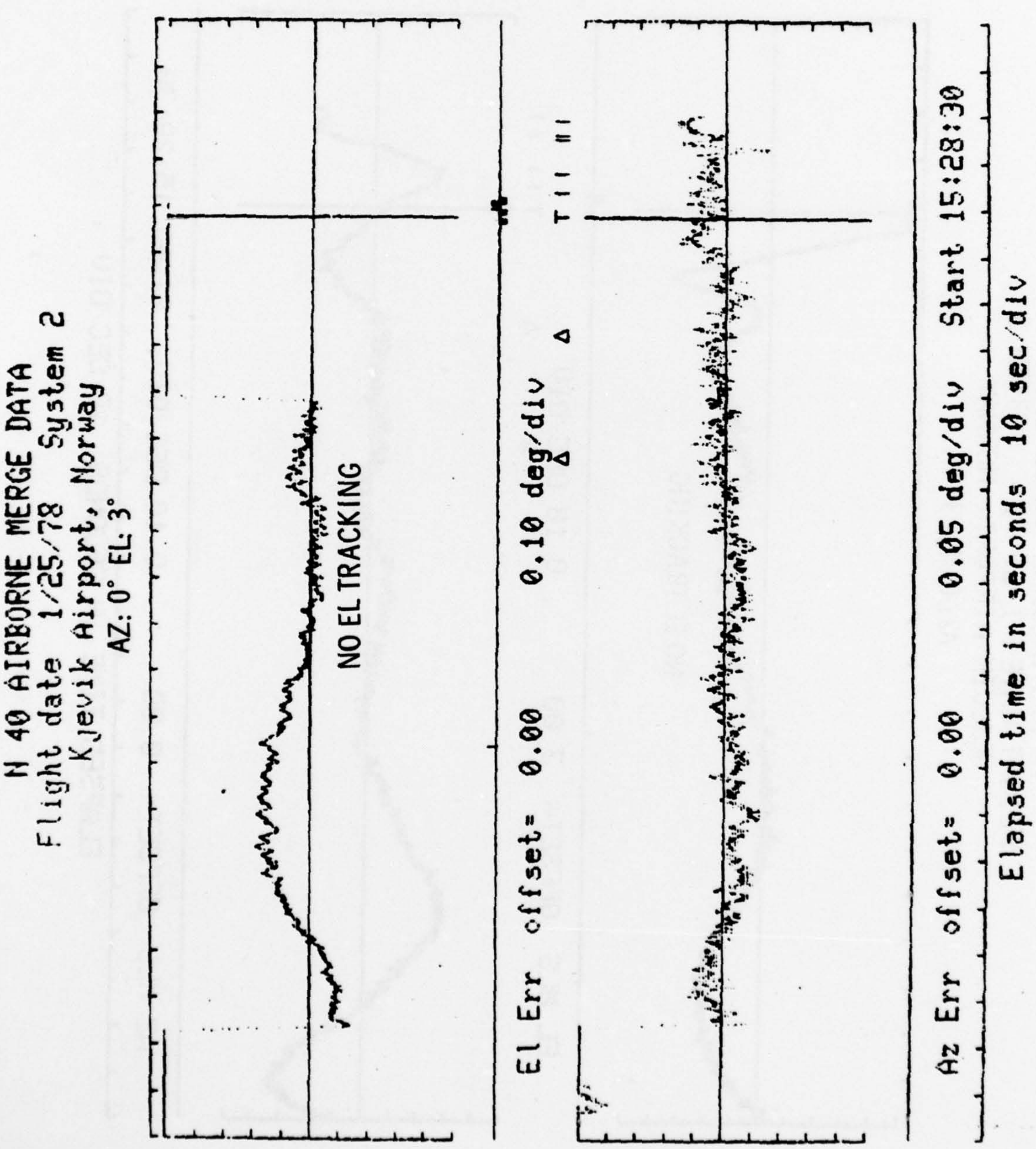



N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 3°L EL: 3°
El Trk offset= 3.00 0.10 deg/div
NO AZ TRACKING
Az Trk offset= 3.00 0.10 deg/div Start 10:52:48
Elapsed time in seconds 10 sec/div


N 40 AIRBORNE MERGE DATA
Flight date 1/25/78 System 2
Kjevik Airport, Norway
AZ: 0° EL: 3°
NO EL TRACKING
El Err offset= 0.00 0.10 deg/div
Az Err offset= 0.00 0.05 deg/div Start 15:28:30
Elapsed time in seconds 10 sec/div

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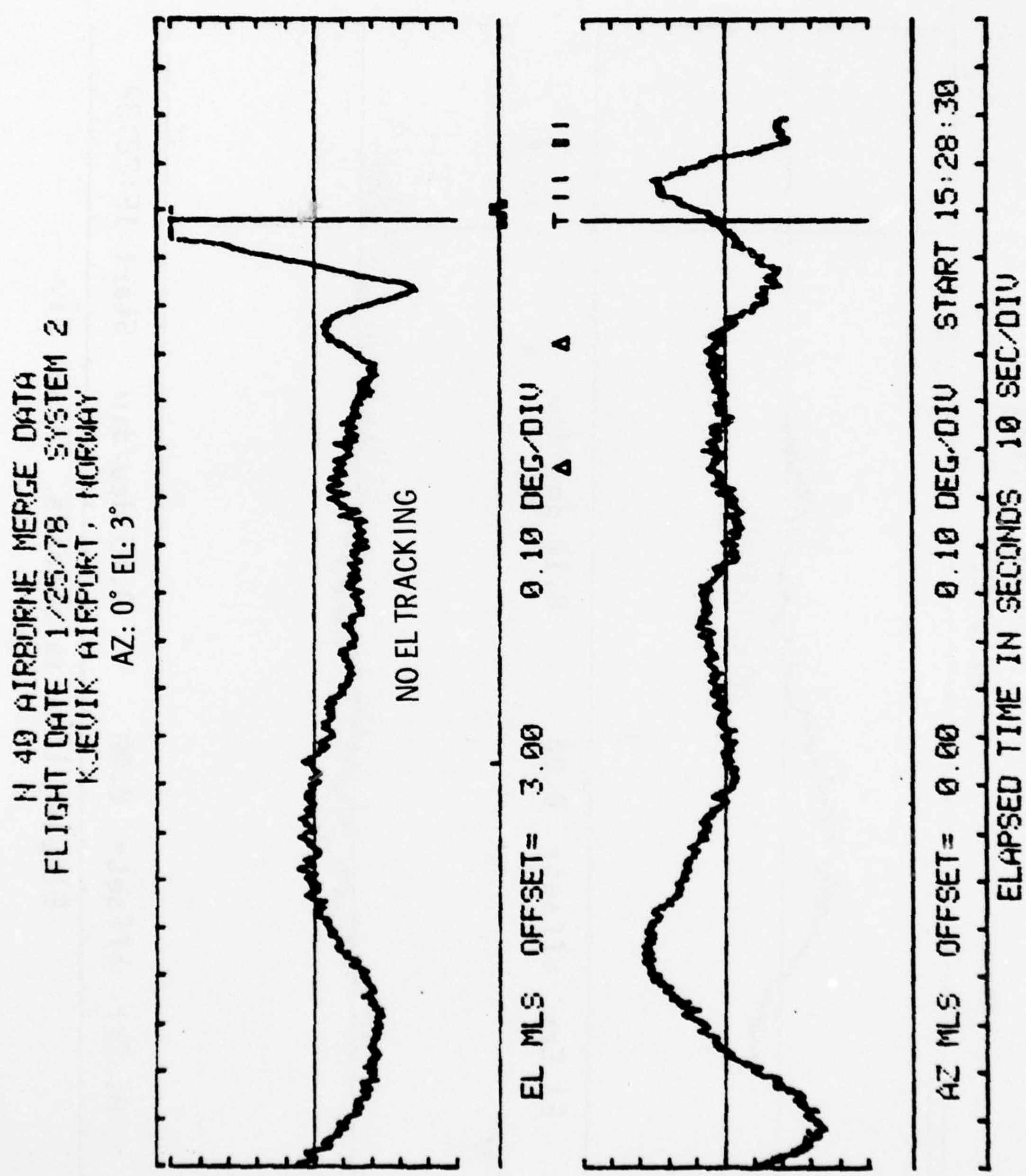

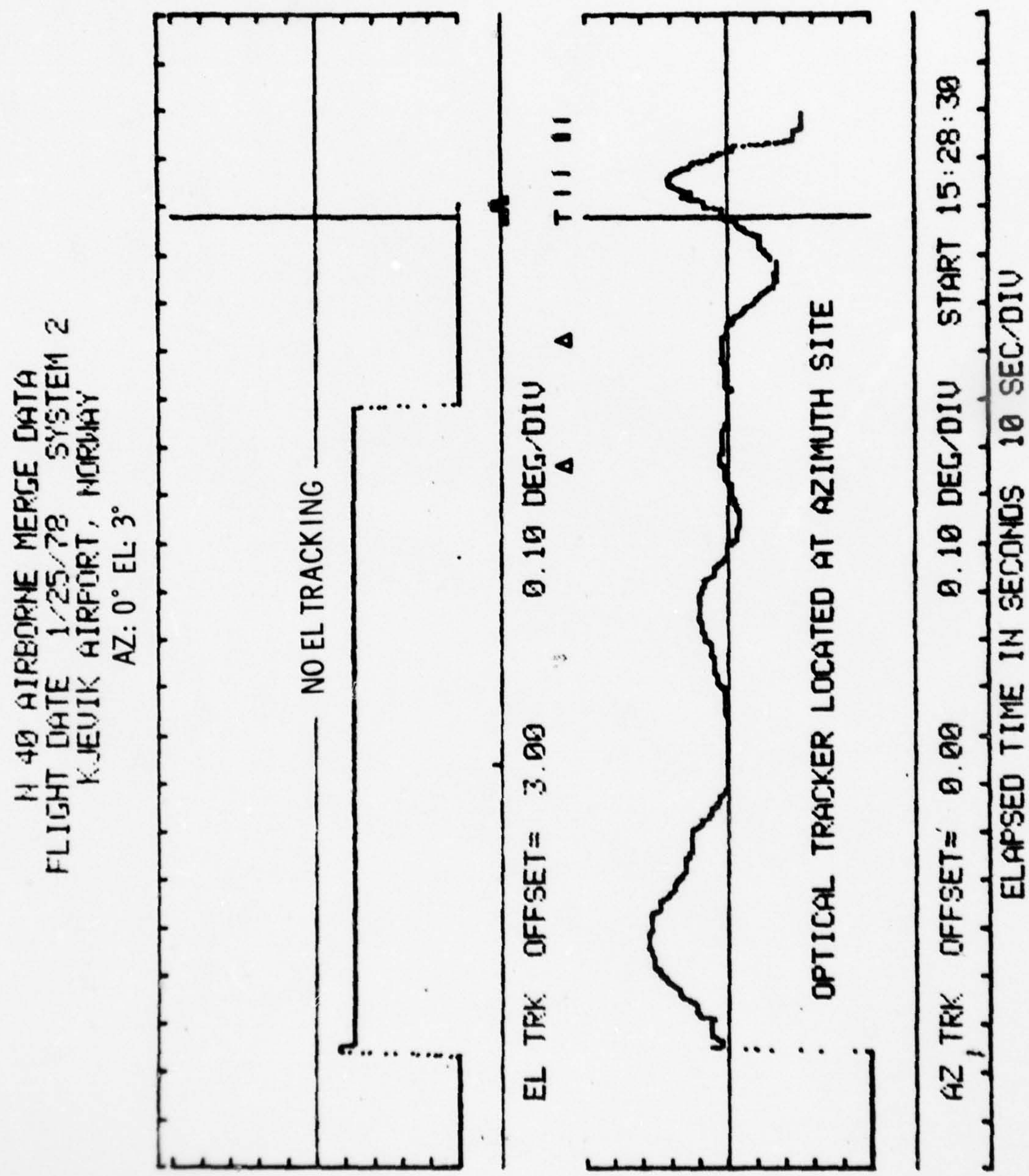
N 40 AIRBORNE MERGE DATA
FLIGHT DATE 1/25/78 SYSTEM 2
KJEVIK AIRFORT, NORWAY
AZ: 0° EL: 3°
NO EL TRACKING
EL TRK OFFSET= 3.00 0.10 DEG/DIV
OPTICAL TRACKER LOCATED AT AZIMUTH SITE
AZ TRK OFFSET= 0.00 0.10 DEG/DIV START 15:28:30
ELAPSED TIME IN SECONDS 10 SEC/DIV