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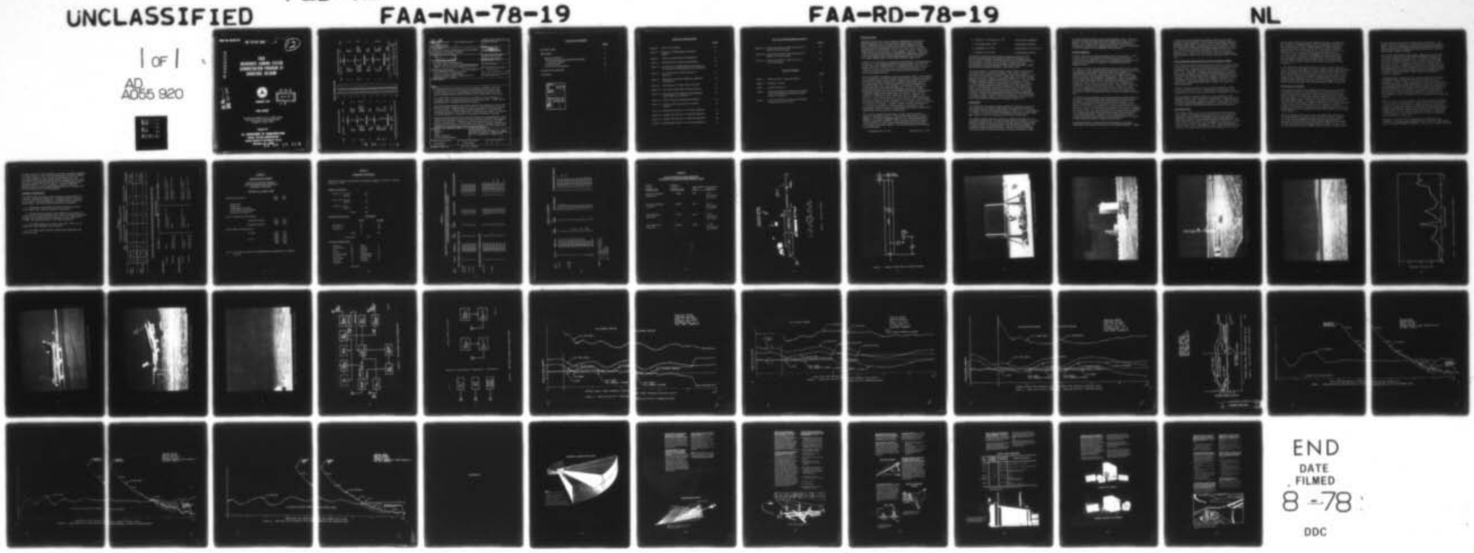

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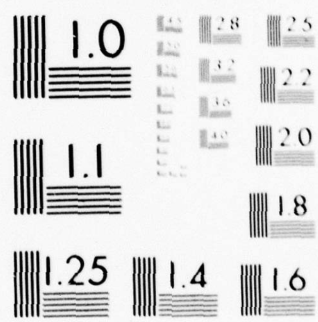

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Report No. FAA-RD-78-19

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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT CHARLEROI, BELGIUM

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FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

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

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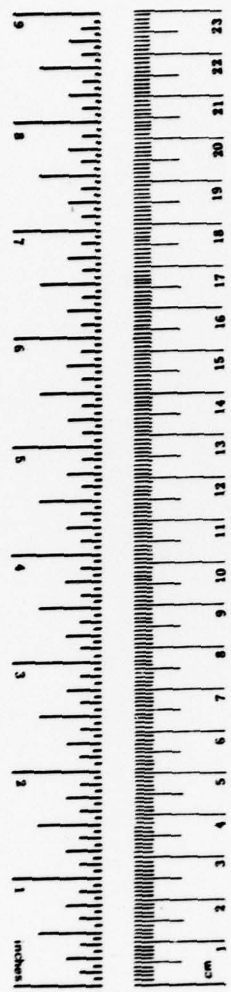
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

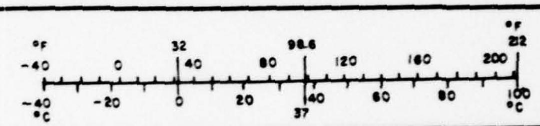
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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 Gosselies Airport, Charleroi, Belgium, was held in conjunction with the United States TRSB demonstration program, and was the sixth in a series of operational demonstrations of several TRSB system configurations at selected airports in the United States and abroad.

The TRSB Small Community System was installed to service Runway 25, the runway with a commissioned Instrument Landing System. Flight checks established that no mutual interference resulted.

Operational demonstrations were made utilizing FAA Boeing 727 and Convair 880 test aircraft. Flight performance data was acquired with the Boeing 727 test aircraft only. Flight profiles included approaches on centerline and offset plus and minus 1 and 2 degrees at various elevation angles, and radials at constant altitude on centerline and offset plus and minus 10 degrees.

Results of the operational demonstrations indicated that the performance of the TRSB Small Community azimuth subsystem met ICAO (AWOP) "full capability system" requirements. Although an accurate assessment of the elevation subsystem performance was not possible due to lack of adequate tracking data, the elevation angle deviations about an averaged value were well within ICAO (AWOP) "full capability system" error limit boundaries.

17. Key Words
Charleroi
TRSB
Small Community
Aircraft Landing System

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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 syatem 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 28 through February 6, 1978, at Gosselies Airport, Charleroi, Belgium, were held in conjunction with the U.S. TRSB demonstration program at Brussels, Belgium. These concurrent efforts in Belgium were the sixth in a series of operational demonstrations at domestic and foreign commercial 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

5. January 23-24, 1978 — Kristiansand, Norway

The TRSB demonstrations at Gosselies Airport afforded civil and military aviation officials and technical experts from Belgium and other European countries, NATO and the General Aviation Community, the opportunity to observe and participate in operational flight demonstrations and inspection of the TRSB Small Community azimuth and elevation subsystems installed on the airport sites.

Gosselies Airport is a small municipal airport located 7.4 kilometers (4.6 miles) north of Charleroi, Belgium. The airport, which is operated by the Belgian Government's Regis Des Vois Aeriennes (RVA), is served by Sabina Airlines with two daily flights to and from London, England, and Liege, Belgium, using Beech 99 aircraft. It is also used for flight training by Sabina and local General Aviation as well as occasional military flight test operations in connection with a fighter aircraft rebuilding factory located at Charleroi. The airport has a single concrete/asphalt runway (07/25) 2550 meters (8366 feet) long and a parallel 500-meter (1640-feet) long grass strip. The existing Category I Instrument Landing System permits precision approaches to Runway 25 which was utilized for the installation of the TRSB Small Community System. Figure 1 shows the airport plan view and location of the TRSB subsystem elements with respect to Runway 25.

DISCUSSION

The TRSB Small Community System installed at Gosselies Airport was manufactured by the Bendix Corporation's Communications Division in accordance with FAA specifications (refer to Table 1). It is representative of a simple, economical system configuration, designed to provide better than Category I service on runways to 1524 meters (5000 feet).

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 provoded between the plus and minus 10-degree azimuth proportional sector out to plus and minus 40 degrees on 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. An auxiliary data channel is included for transmission of facility status information to approaching aircraft. General information on TRSB is contained in the Appendix to this document.

System Installation

An FAA advance team visited Gosselies Airport on December 6, 1977, to select sites for installation of the TRSB azimuth and elevation subsystems and to make the necessary arrangements for ground service support of the equipment installation and scheduled operational demonstrations.

On January 28, 1978, the FAA Boeing 727 test aircraft, N-40, arrived at Gosselies Airport transporting the TRSB Small Community System and supporting FAA personnel. During that day, the equipment was unloaded from the aircraft, transported to the azimuth and elevation sites, assembled, and installed. By January 30, 1978, both azimuth and elevation subsystems had been mechanically aligned, operationally ground checked and flight tested. Some delay was encountered in completion of the system operational checkout due to difficulties in establishing intersite signal synchronization. This problem which was caused by a hump in the terrain between the two sites, was finally resolved by installing the sync antenna 12.5 meters (41 feet) above ground level on the ILS glide slope antenna tower at the TRSB elevation site.

The TRSB azimuth subsystem was located along the extended centerline 30 meters (98 feet) beyond the stop end of Runway 25 which placed it 100 meters (328 feet) in front of the airport's ILS localizer. The elevation subsystem was located offset 79 meters (259 feet) north of Runway 25 centerline at a position 311 meters (1020 feet) from the start end of the runway. The operational threshold for this runway is displaced 410 meters (1345 feet) from the start end of the runway; thereby placing the ILS glide slope and collocated TRSB elevation subsystem in front of the landing threshold. Collocation of the TRSB system with the airport's ILS had no adverse affect on the ILS performance as verified in flight checks witnessed by Belgian RVA personnel.

Detailed information on siting of the TRSB azimuth and elevation subsystems with respect to Runway 25, is provided in Figure 2. Figure

3 shows the azimuth subsystem installation with the airport's ILS localizer in the background. Figure 4 shows the elevation subsystem installation while Figure 5 is an overall view of the TRSB elevation site showing the airport's ILS glide slope in the background. Figure 6, a view down the centerline of Runway 25 taken from the stop end, shows the horizon profile and obstructions along the centerline approach path. Figure 7 presents details of the horizon profile as measured from a position near the runway edge at the TRSB elevation site.

TRSB Operational Demonstrations and Data Acquisition Flights

TRSB operational flight demonstrations in the FAA-727 (Figure 8) and CV-880 (Figure 9) test aircraft and ground tours for inspection of the equipment, were conducted at Gosselies Airport on February 1, 2, and 3, 1978. This effort, similar concurrent activity at Zaventem Airport near Brussels, and technical briefings/discussions held at the Holiday Inn, Diegem supported the Brussels TRSB demonstration program. Tables 2 and 3 present the program's schedule of events and summary statistics, respectively. Details of the Zaventem installation and operational flight demonstrations is contained in a separate document.

A total of 12 data acquisition runs were flown with the B-727 test aircraft on February 5, 1978. Flight details for both operational demonstration and data acquisition activities are presented in Table 4.

Prevailing adverse weather conditions of rain, light snow, and limited visibility, made it difficult to consistently accomplish optical tracking of the aircraft. Figure 10, which is a view of the FAA B-727 test aircraft making an approach to Runway 25, illustrates the limited visibility conditions encountered during one period on February 5.

Airborne System

The airborne TRSB system in the B-727 and CV-880 test aircraft were similar, consisting of dual angle receivers, course direction indicators, and precision L-band distance measuring equipment (DME) interrogators. Instrumentation used for data acquisition was also similar and 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 from the TRSB ground sites. Although both test aircraft were equipped with precision L-band DME interrogators, this equipment was not used in flights against the Small Community System at Gosselies Airport since there was no ground transponder installed there. These interrogators were operational, however, and were used on intervening runs flown against the TRSB system at Zaventem Airport. It should be noted that precision L-band DME is not necessarily a component of the TRSB Small Community System. The interrelation of the airborne TRSB system and instrumentation with the aircraft's flight control systems in the two aircraft is shown in Figure 11.

A wide angle, plus and minus 85 degrees, antenna mounted in the nose section of each aircraft within the weather radome, and an omni-directional antenna mounted on the fuselage of each aircraft just above the center of the cockpit windshield (refer to Figures 8 and 9), were available so that either could be alternately switched to either of the TRSB angle receivers installed in the respective aircraft. It should be noted, however, that for all the data presented in this document, only the angle data from the TRSB receiver connected to the omni-directional antenna was utilized.

Performance Assessment

Ground based tracking for the TRSB demonstration effort was provided by two different types of optical trackers. One of the trackers was a manually operated radio-telemetry theodolite (RTT) used to transmit either azimuth or elevation angle position, depending upon its siting for particular flights, to the aircraft via a transmitter operating on an unused UHF glide slope channel. The other tracker system, used alternately with the RTT to track either azimuth or 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.

During the flights, the portable tracker equipment were positioned at the respective TRSB azimuth and elevation sites as follows: Azimuth site on the antenna radiation centerline directly below the antenna enclosure; at the elevation site, offset from the TRSB elevation antenna enclosure toward the runway approximately 4.6 meters (15 feet). For the operational demonstration flights, the RTT tracker was positioned at the elevation site and the optical tracker at the azimuth site. The location of the two trackers was interchanged for the data acquisition flights. Although simultaneous tracking of azimuth and elevation was made during each run, tracking data from both trackers was seldom obtained due to limited visibility.

The azimuth and elevation analog tracker angle data received in the aircraft was subtracted from the TRSB azimuth and elevation 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.

A sampling of data reproduced from airborne strip chart recordings, made during flights conducted in the FAA B-727 test aircraft on February 1, 3, and 5, 1978, are presented in Figures 13 through 19. For data presentation, small alignment bias errors have been removed. The longitudinal axis of these plots represents range from Runway 25 threshold determined from notations on the original strip charts of the aircraft passing over the runway's "outer marker, middle marker, and threshold." ICAO error limit boundaries (refer to Table 5) for "full capability system" configuration, have been included on the applicable figures.

Figures 13, 14, 15, and 16 which are zero degree azimuth approaches on a 3.0-degree elevation approach angle, show that for the regions of valid tracking, between 1 and 2-3/4 nautical miles, the TRSB Small Community azimuth subsystem was within ICAO (AWOP) "full capability system" requirements. Although the elevation subsystem data shown in Figures 13, 14, and 15 appears relatively smooth, no assessment of the elevation error could be made because elevation tracking data was not obtained for these runs.

Figures 17, 18, and 19 are azimuth radials of 10 degrees left of centerline, 10 degrees right of centerline and on centerline respectively, flown at a constant altitude of 2000 feet. There was no azimuth or elevation tracking obtained for these particular runs due to visibility conditions of 3 miles and less. For each of the three plots, the ICAO (AWOP) error limit boundary of ±0.1 degree in elevation for the "full capability system" has been placed around a segment of the elevation trace which represents the test aircraft crossing through elevation approach angles of 3.5 and 4.0 degrees. Review of this data indicates that the elevation angle deviations about an averaged value are well within the error limit boundaries.

SUMMARY OF RESULTS

The TRSB system discussed in this document is representative of a simple, economical configuration of TRSB hardware referred to as the "Small Community System." In addition to the economical design feature, the information presented herein indicates:

1. Performance of the TRSB azimuth subsystem was within ICAO (AWOP) "full capability system" requirements.

2. Although the performance of the TRSB elevation subsystem could not be accurately assessed, due to the lack of adequate elevation tracking, the elevation angle data obtained was well within ICAO (AWOP) "full capability system" error limit boundaries.

3. The TRSB system can be used on the same runway as ILS without adversely affecting ILS performance.

4. The TRSB system required minimal site preparation and installation time.

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	PFE Degradation W/Azimuth Angle	PFE Degradation 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

SCHEDULE OF EVENTS

UNITED STATES OF AMERICA
TRSB DEMONSTRATION PROGRAM
BRUSSELS, BELGIUM

February 1, 2, and 3, 1978

TRSB Demonstration		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

SUMMARY STATISTICS

TRSB operational demonstrations 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	CV-880
February 1	27	21
February 2	27	46
February 3	11	53
Total	65	120
Grand Total	185	

Countires Represented

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

Total 185

TABLE 4

TRSB OPERATIONAL DEMONSTRATIONS AND DATA ACQUISITION FLIGHTS AT GOSSELIES AIRPORT, CHARLEROI, BELGIUM

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial/Constant Altitude
FAA Convair CV-880 Testbed Aircraft						
1/30/78	1	Approach	0°	3°	6 nmi	I - 1900 feet
2/1/78	1	Approach	0°	3°	6 nmi	I - 1900 feet
	2	Approach	0°	3°	6 nmi	I - 1900 feet
2/2/78	1	Approach	0°	3°	6 nmi	I - 1900 feet
	2	Approach	0°	3°	6 nmi	I - 1900 feet
2/3/78	1	Approach	0°	3°	6 nmi	I - 1900 feet
	2	Approach	0°	3°	6 nmi	I - 1900 feet
FAA Boeing B-727 Testbed Aircraft						
1/31/78	1	Approach	0°	3°	10 nmi	I - 3,100 feet
	2	Approach	0°	3°	10 nmi	I - 3,100 feet
	3	Approach	0°	3°	10 nmi	I - 3,100 feet
	4	Approach	0°	3°	10 nmi	I - 3,100 feet
2/1/78	1	Approach	2° L	3°	8 nmi	I - 2,500 feet
	2	Approach	0°	4°	8 nmi	I - 3,400 feet AL
	3	Approach	0°	3°	8 nmi	I - 2,500 feet
	4	Approach	0°	4°	8 nmi	I - 3,400 feet AL
	5	Approach	0°	4°	8 nmi	I - 3,400 feet
	6	Approach	0°	3°	8 nmi	I - 2,500 feet
	7	Approach	0°	3°	8 nmi	I - 2,500 feet AL

TABLE 4 (continued)

Date	Run #	Type Run	AZ Angle	EL Angle	Start Distance	Initial/Constand Altitude
2/2/78	1	Approach	0°	4°	8 nmi	I - 3,400 feet
	2	Approach	0°	3°	10 nmi	I - 3,400 feet
	3	Approach	0°	3°	10 nmi	I - 3,100 feet AL
	4	Approach	0°	4°	10 nmi	I - 3,900 feet
2/3/78	1	Approach	0°	3°	8 nmi	I - 2,500 feet AL
2/5/78	1	Approach	0°	3°	8 nmi	I - 2,500 feet
	2	Approach	1°R	3°	8 nmi	I - 2,500 feet
	3	Approach	1°L	3°	8 nmi	I - 2,500 feet
	4	Approach	2°R	3°	8 nmi	I - 2,500 feet
	5	Approach	0°	4°	6 nmi	I - 2,500 feet
	6	Approach	1°R	4°	6 nmi	I - 2,500 feet
	7	Approach	1°L	4°	6 nmi	I - 2,500 feet
	8	Approach	0°	2.5°	6 nmi	I - 1,600 feet
	9	Radial	10°L	3°	6 nmi	C - 2,000 feet
	10	Radial	10°R	3°	6 nmi	C - 2,000 feet
	11	Radial	0°	3°	6 nmi	C - 2,000 feet
	12	Approach	0°	2.5°	6 nmi	I - 1,600 feet

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

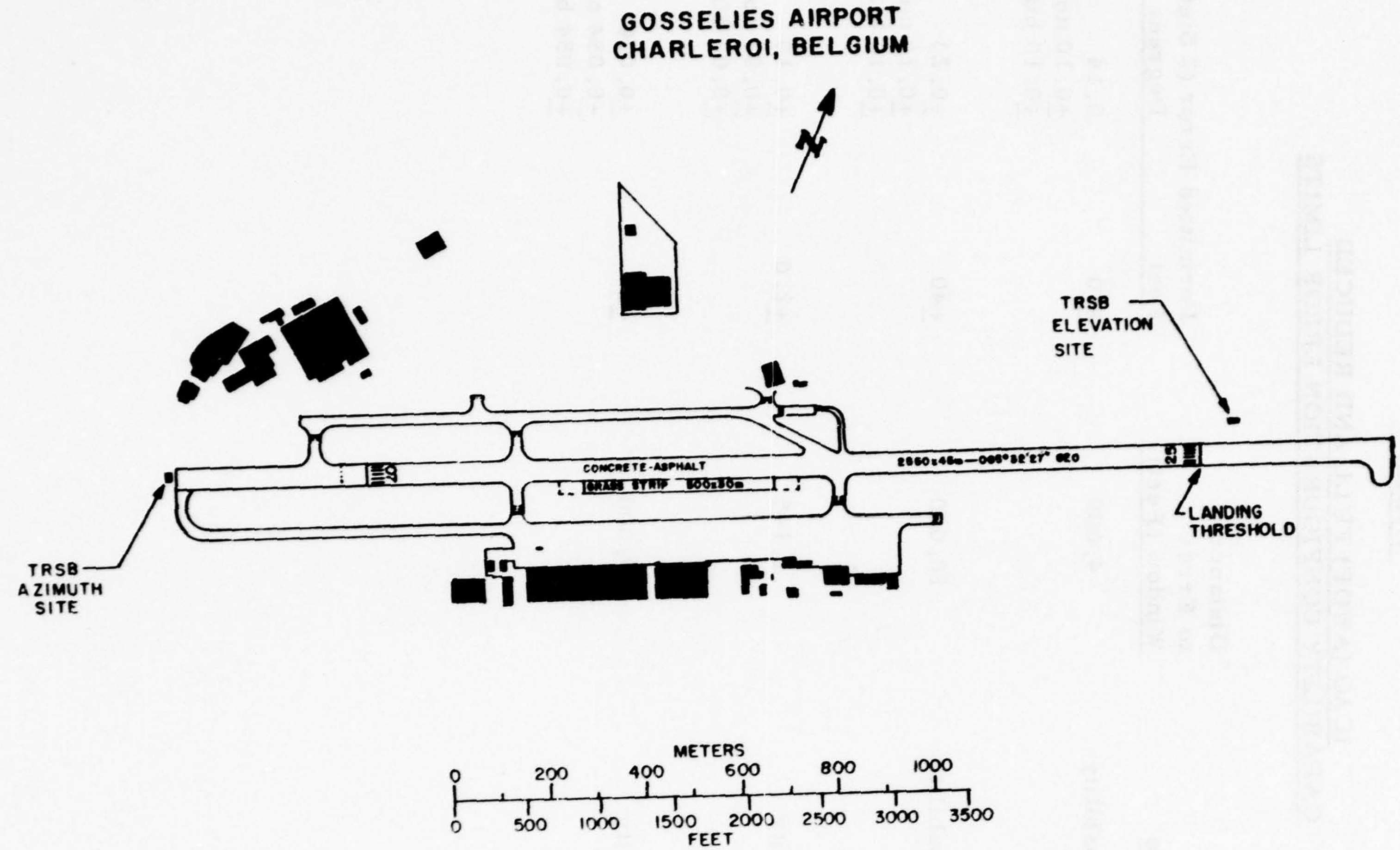


FIGURE 1. PLAN VIEW OF RUNWAY

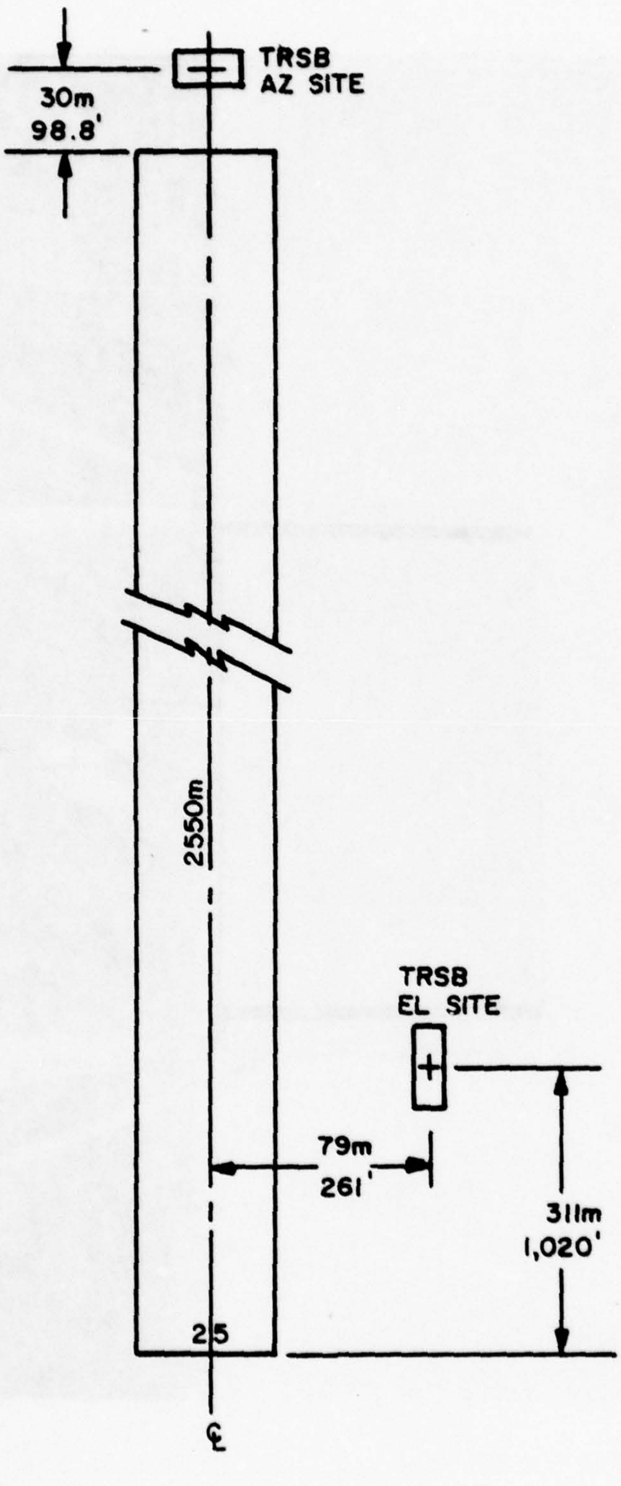


FIGURE 2. DIAGRAM OF TRSB SITING AT GOSSELIES AIRPORT

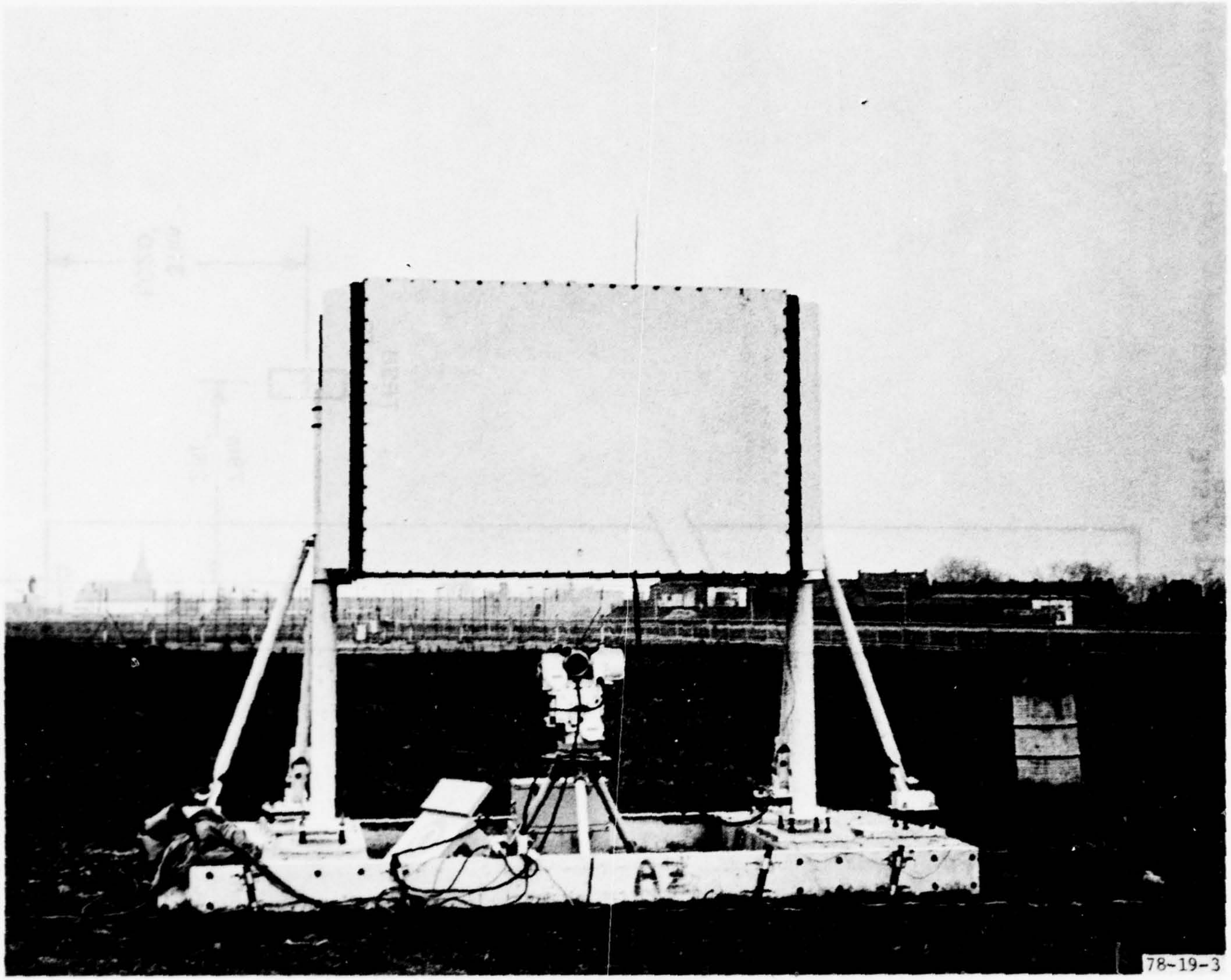


FIGURE 3. TRSB AZIMUTH SUBSYSTEM INSTALLATION

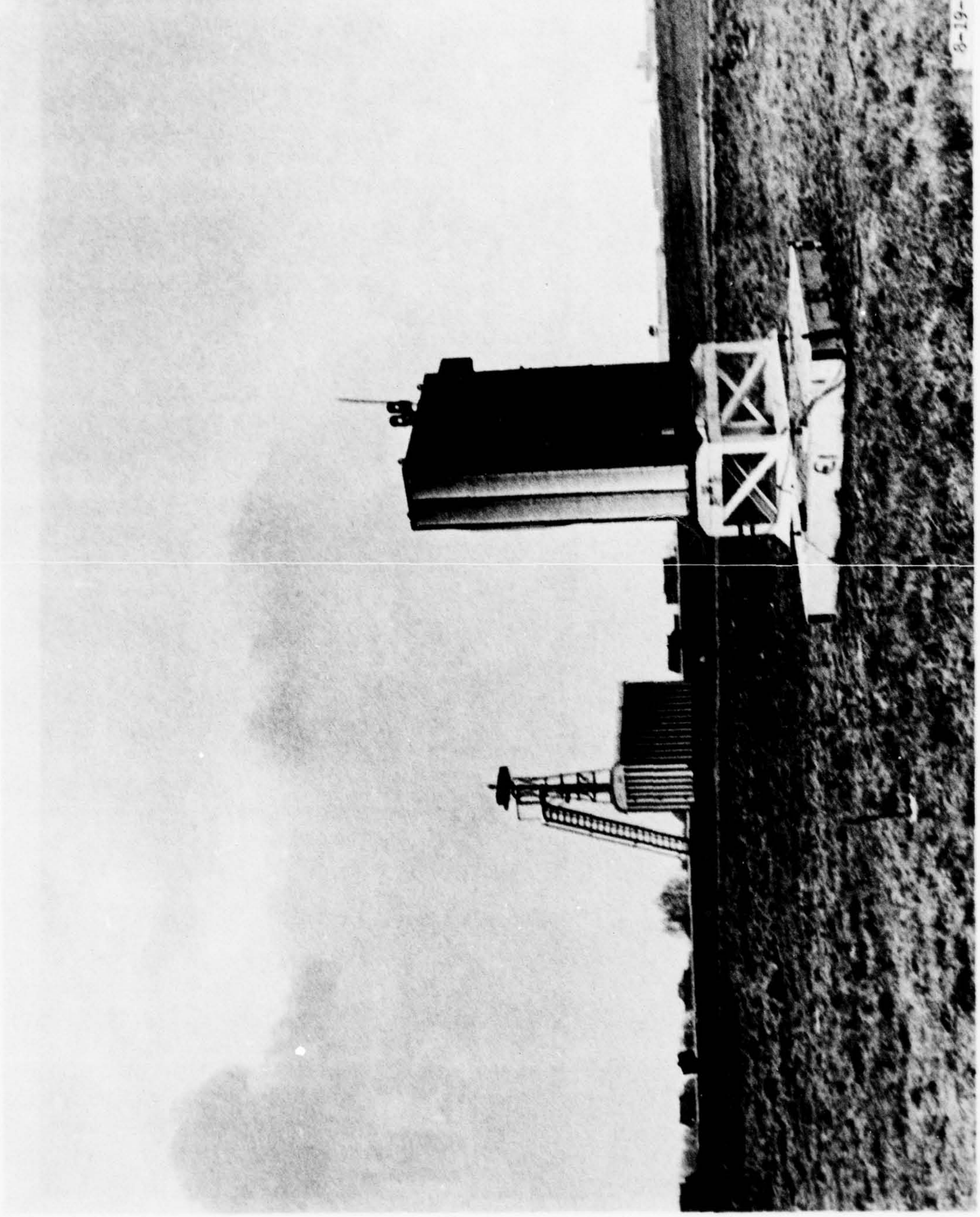


FIGURE 4. TRSB ELEVATION SUBSYSTEM INSTALLATION

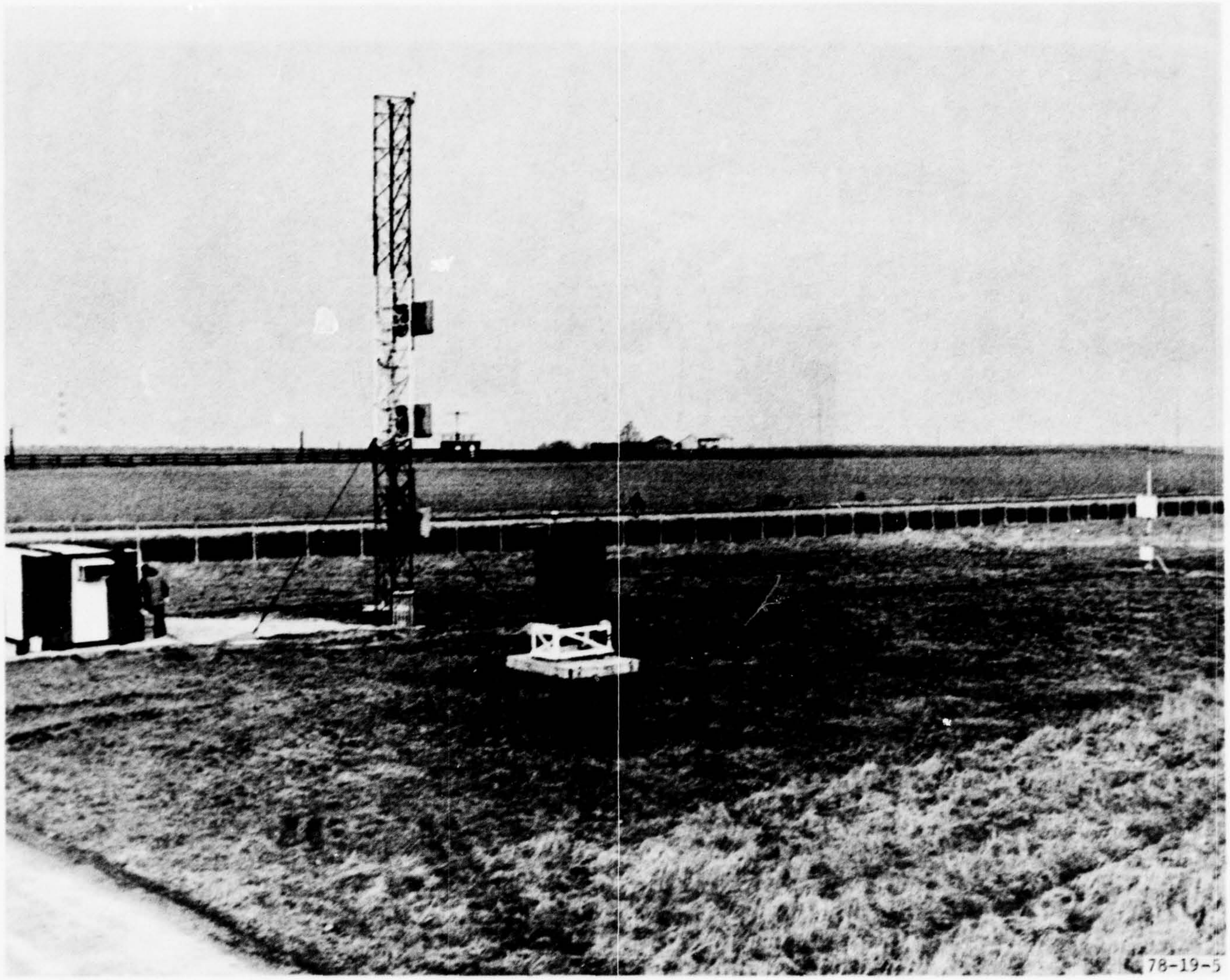


FIGURE 5. OVERALL VIEW OF TRSB ELEVATION SITE SHOWING THE AIRPORT'S ILS GLIDESLOPE IN THE BACKGROUND

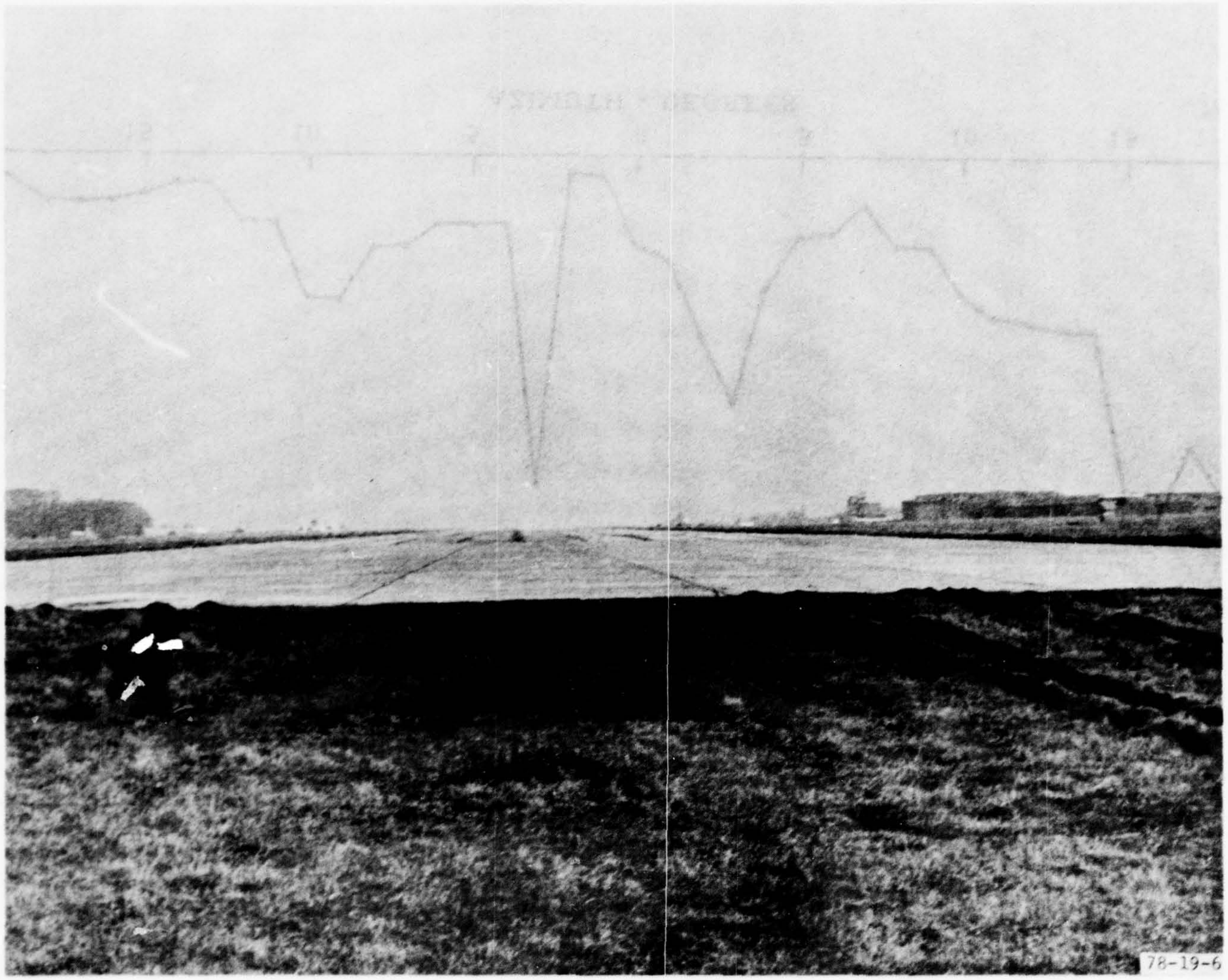


FIGURE 6. VIEW OF GOSSELIES AIRPORT RUNWAY 25 APPROACH

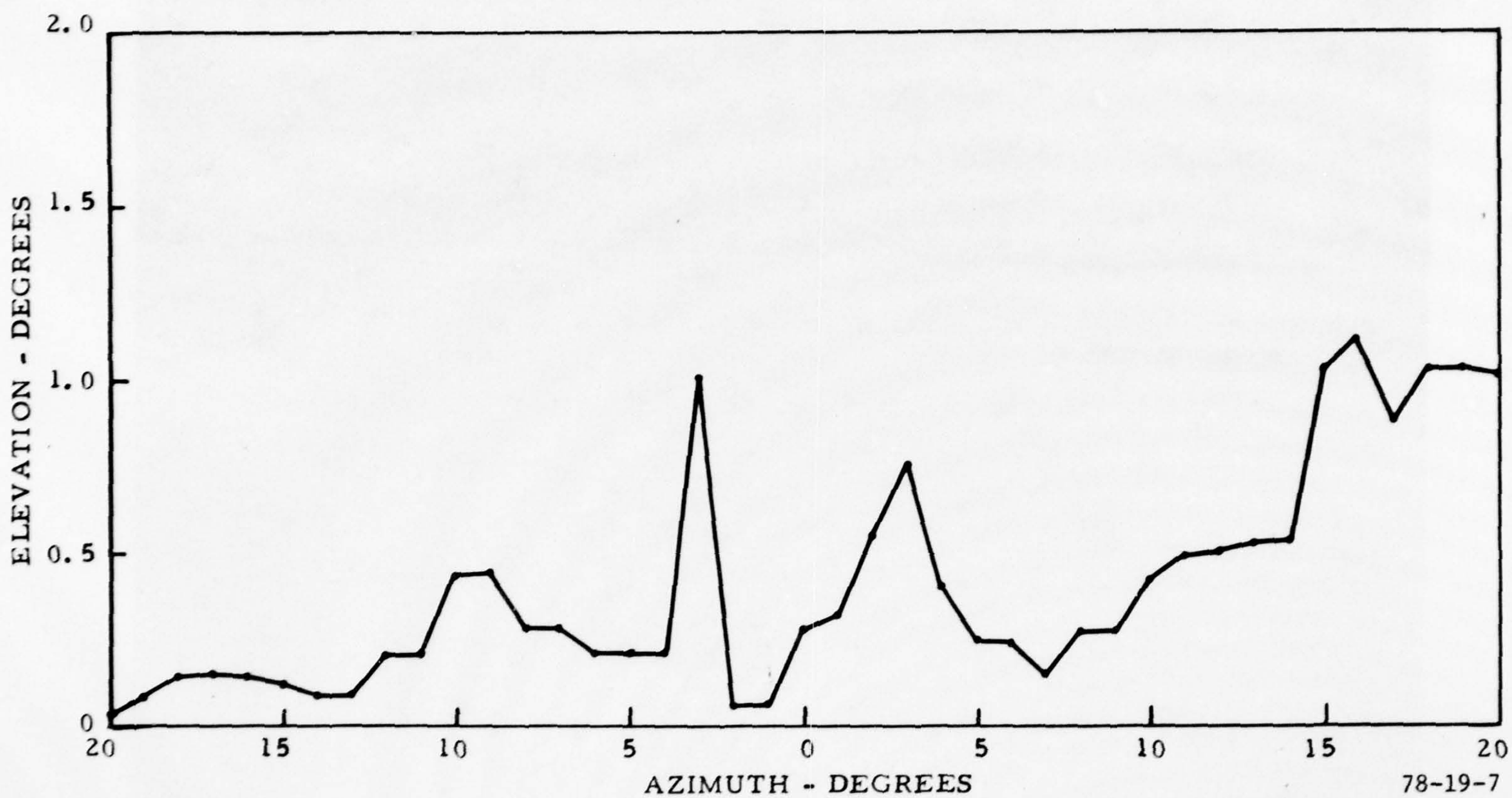


FIGURE 7. OBSTRUCTION CLEARANCE ANGLES FOR APPROACH TO RUNWAY 25

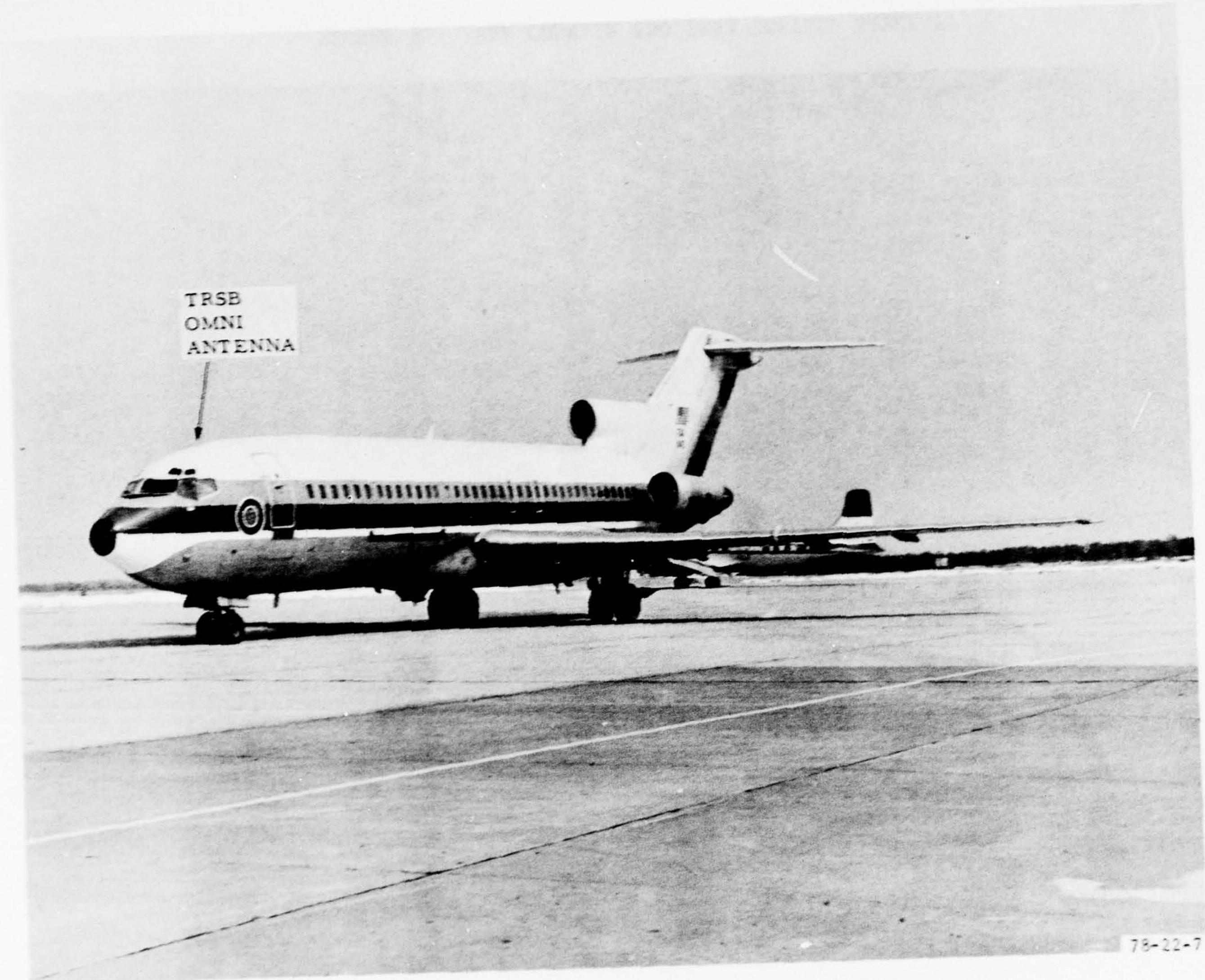


FIGURE 8. FAA BOEING 727 TRSB TESTBED AIRCRAFT

FIGURE 9. FAA CONVAIR 880 TRSB TESTBED AIRCRAFT

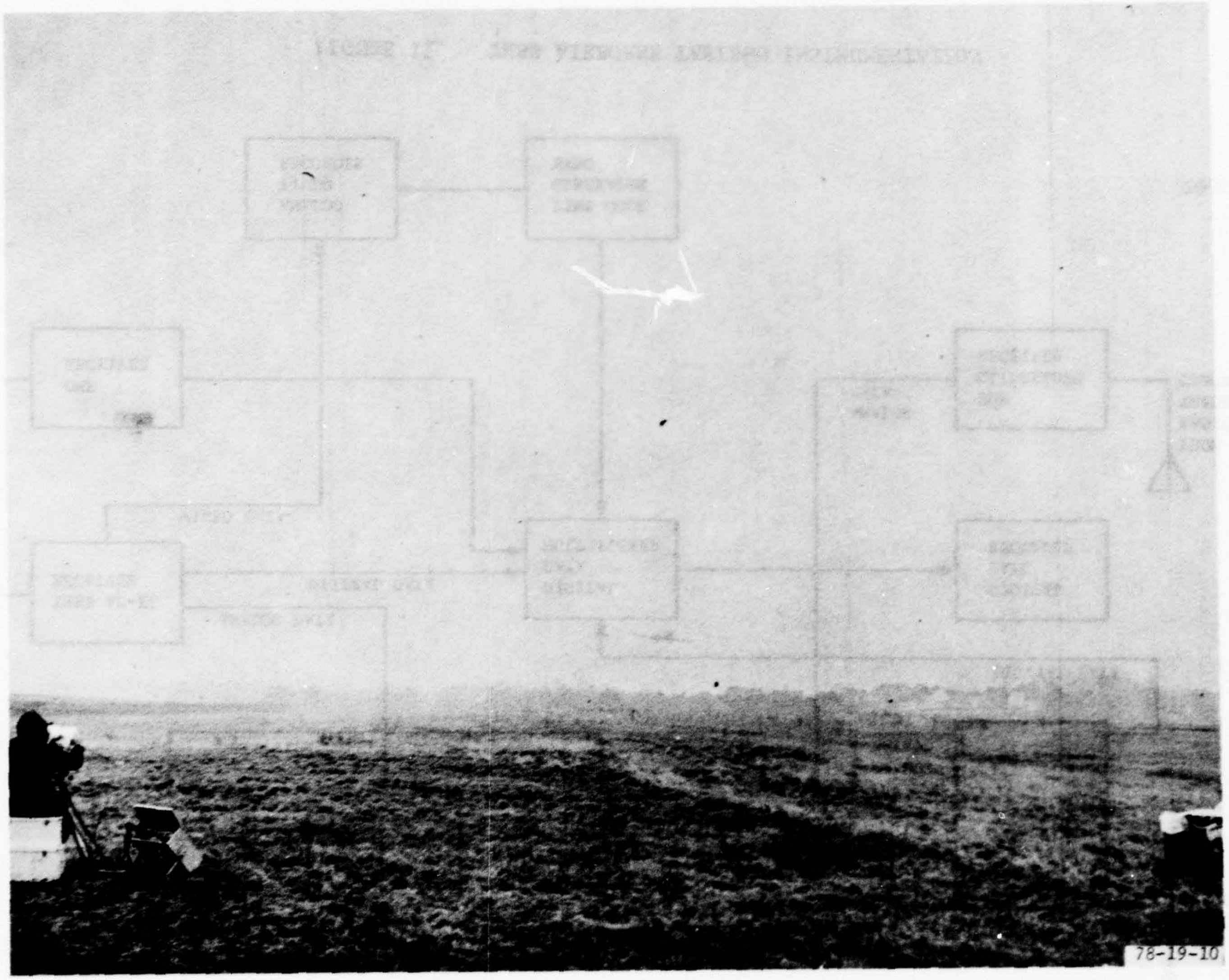


FIGURE 10. FAA BOEING 727 TESTBED AIRCRAFT MAKING A TRSB APPROACH TO RUNWAY 25

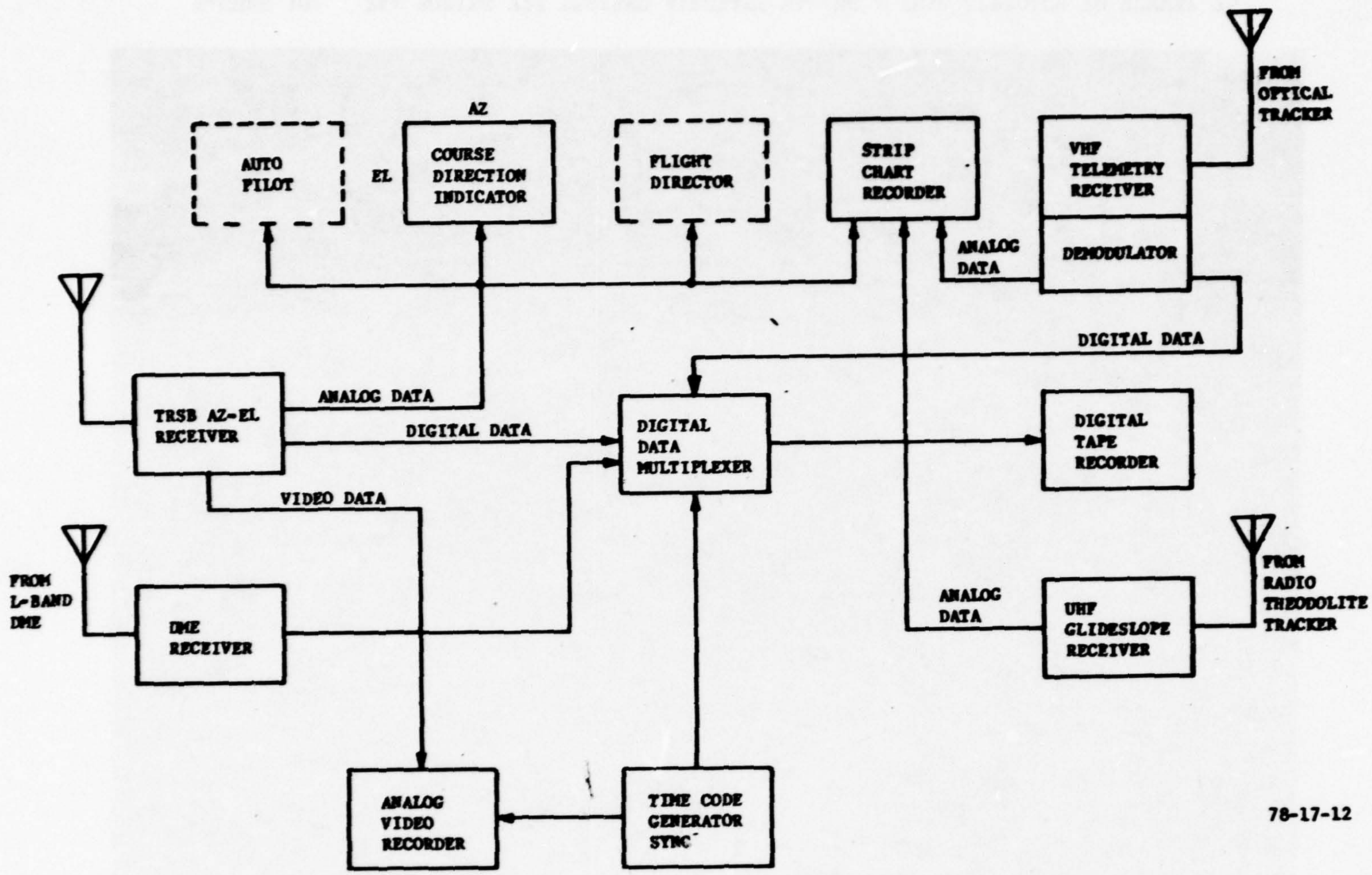


FIGURE 11. TRSB AIRBORNE TESTBED INSTRUMENTATION

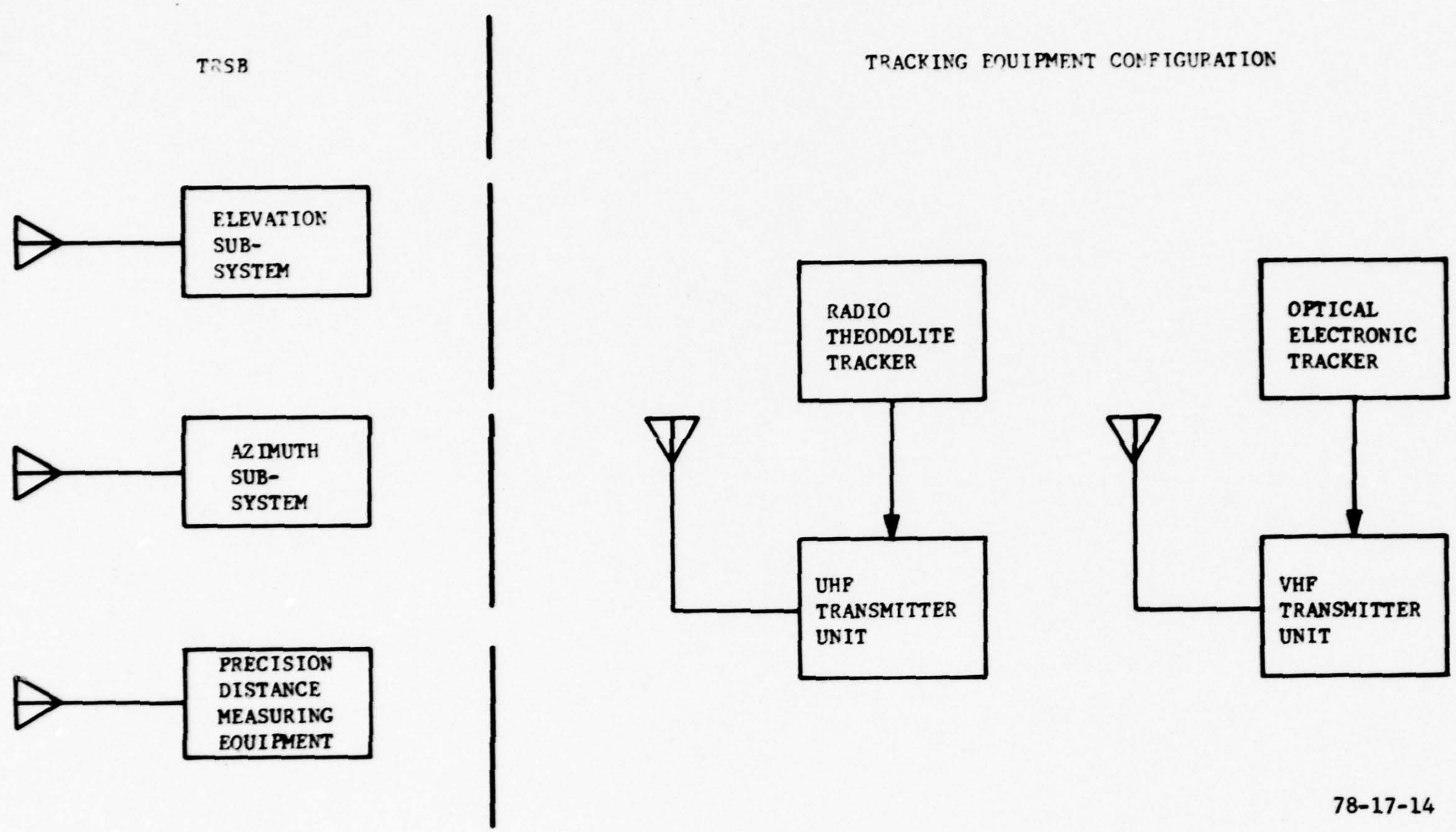


FIGURE 12. TRSB GROUND EQUIPMENT AND TRACKING SYSTEMS

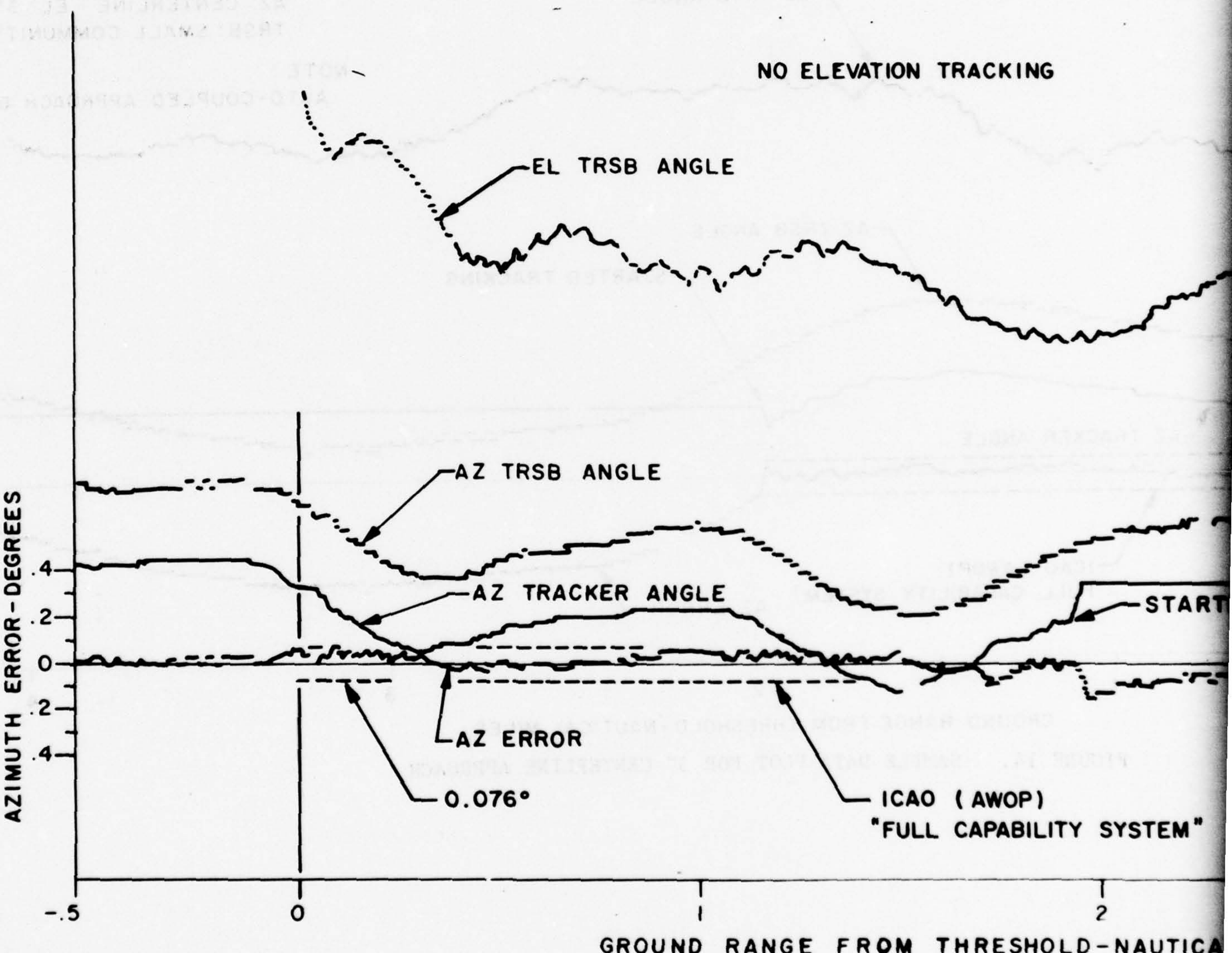
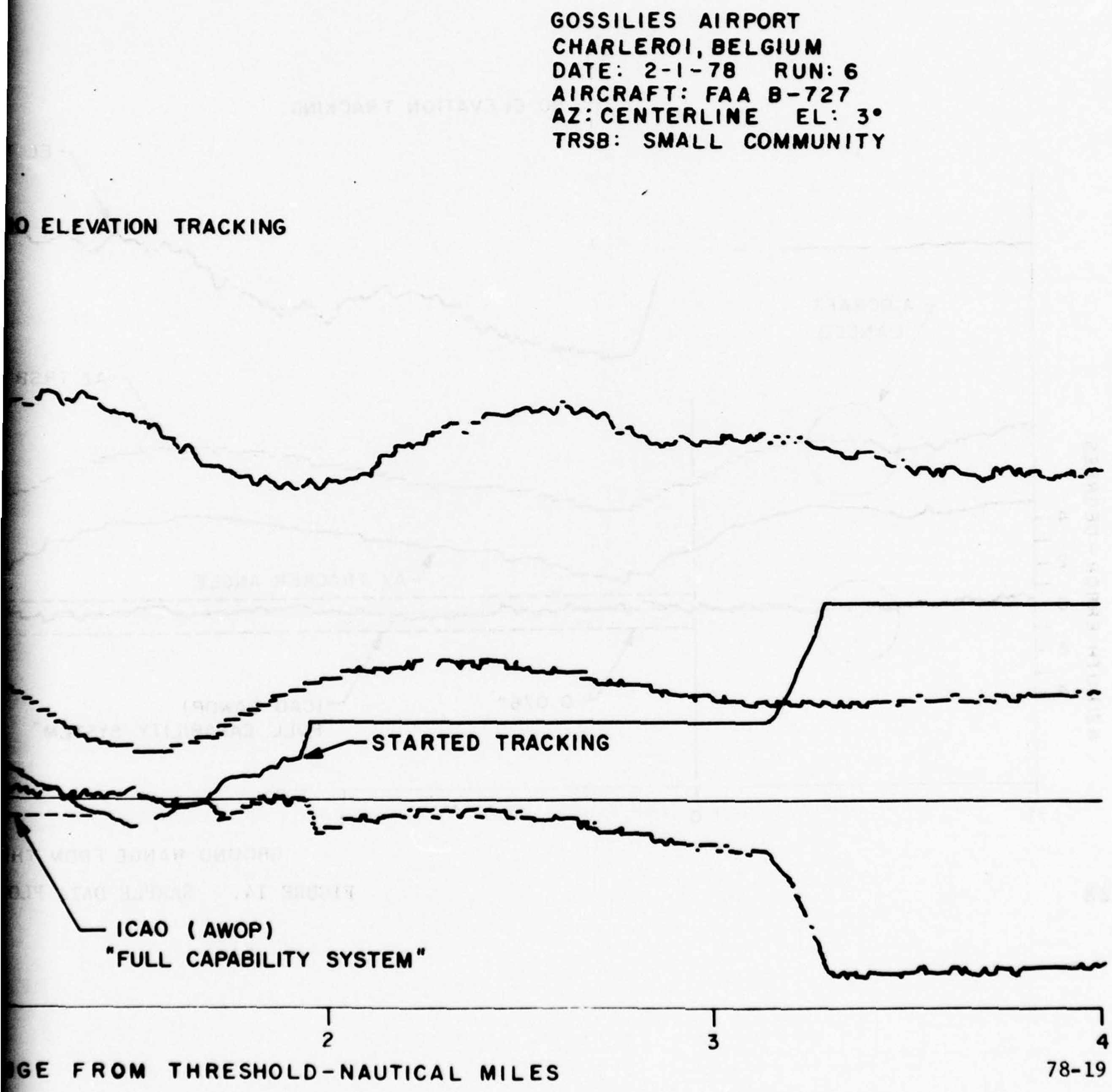


FIGURE 13. SAMPLE DATA PLOT FOR 3° CENTERLINE



SAMPLE DATA PLOT FOR 3° CENTERLINE APPROACH

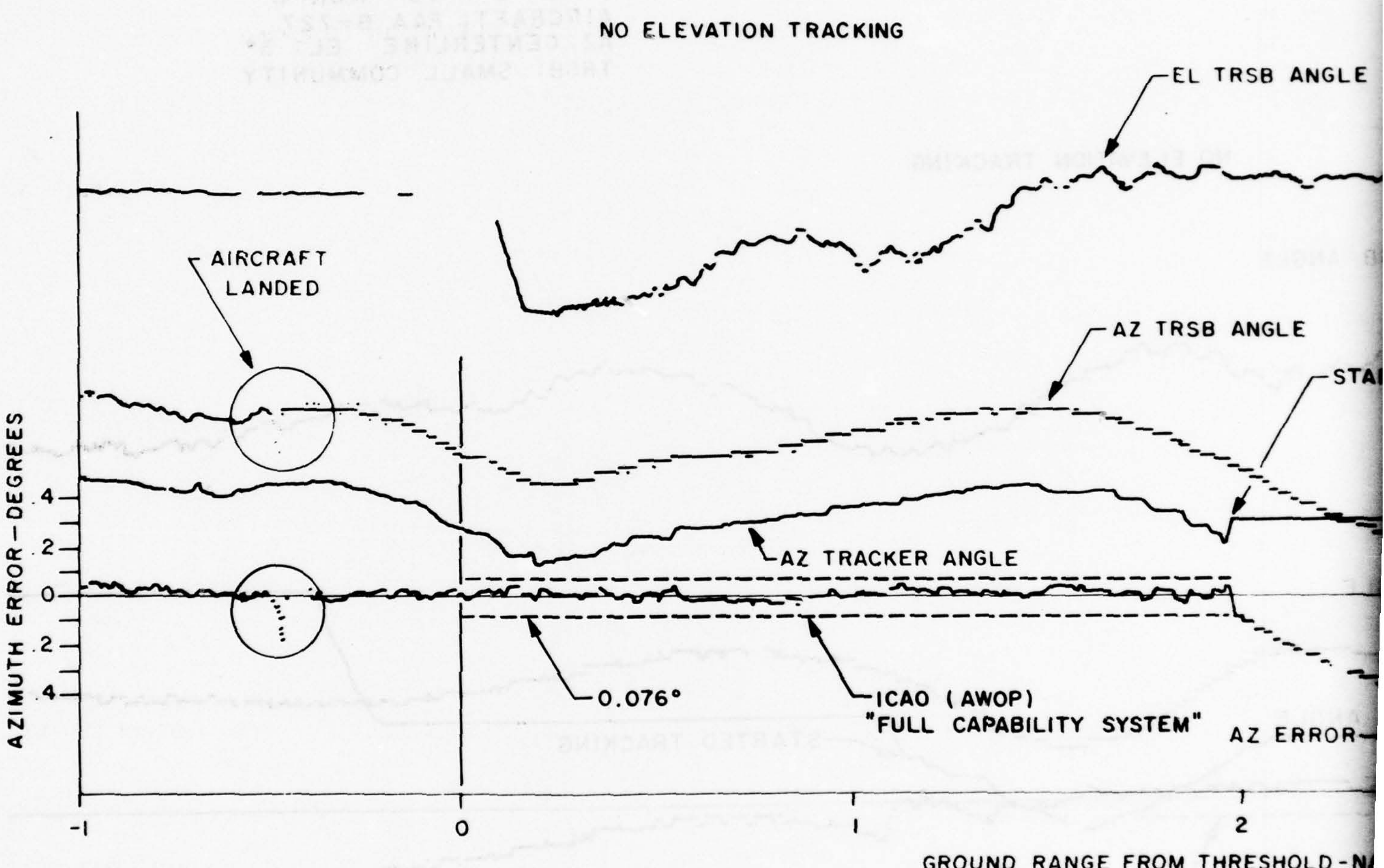
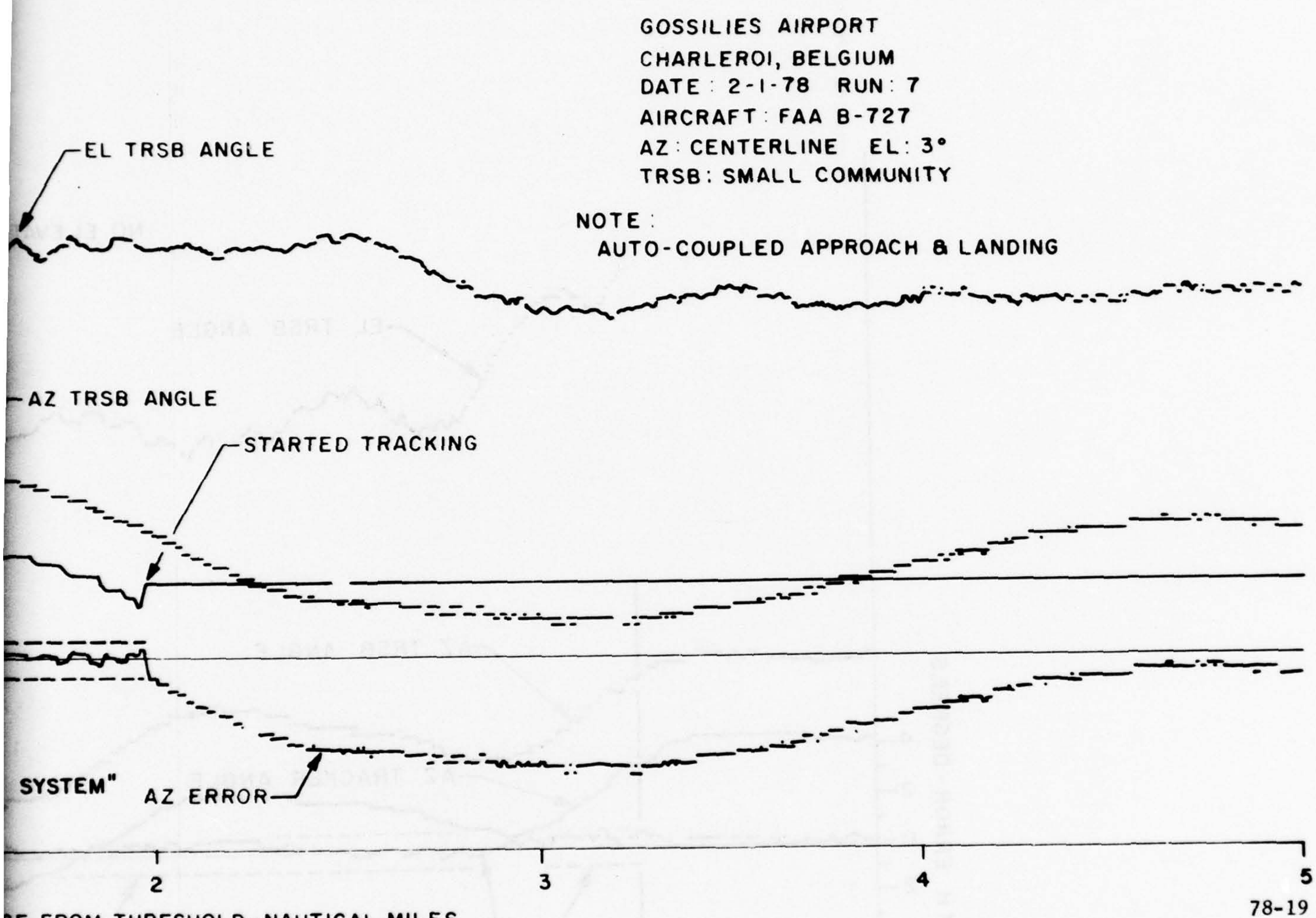


FIGURE 14. SAMPLE DATA PLOT FOR 3° C



LE DATA PLOT FOR 3° CENTERLINE APPROACH

2

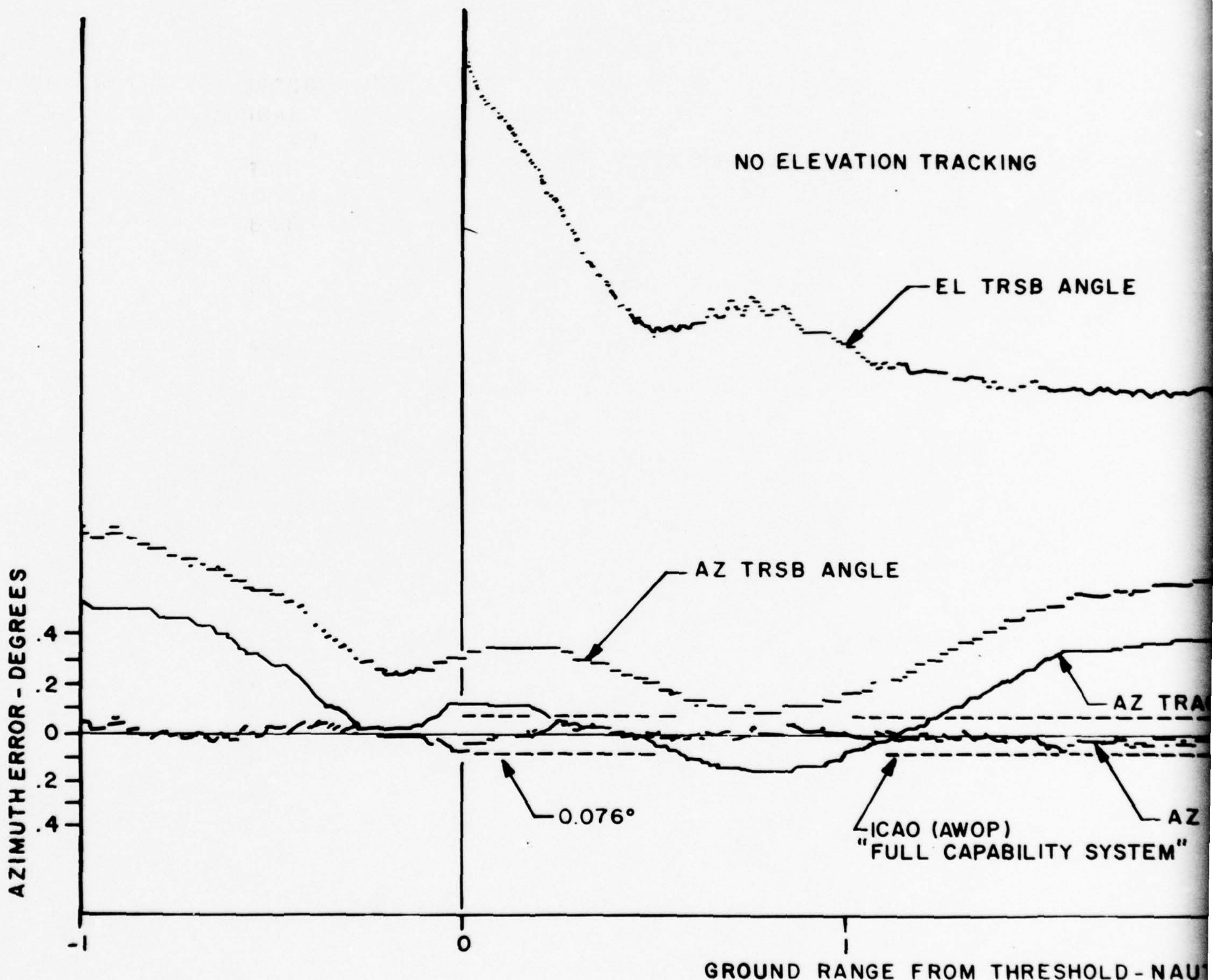
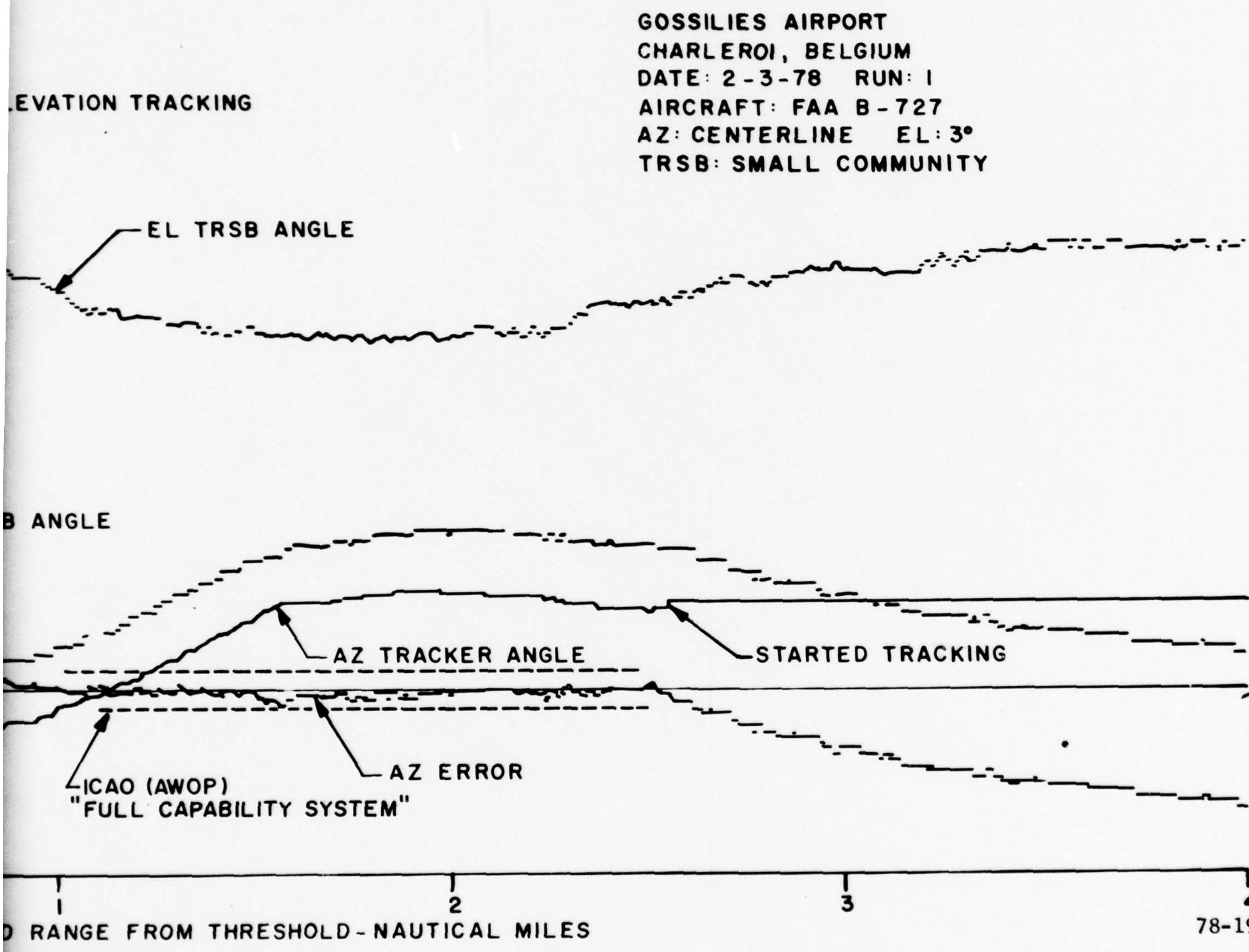


FIGURE 15. SAMPLE DATA PLOT FOR 3° CENT



5. SAMPLE DATA PLOT FOR 3° CENTERLINE APPROACH

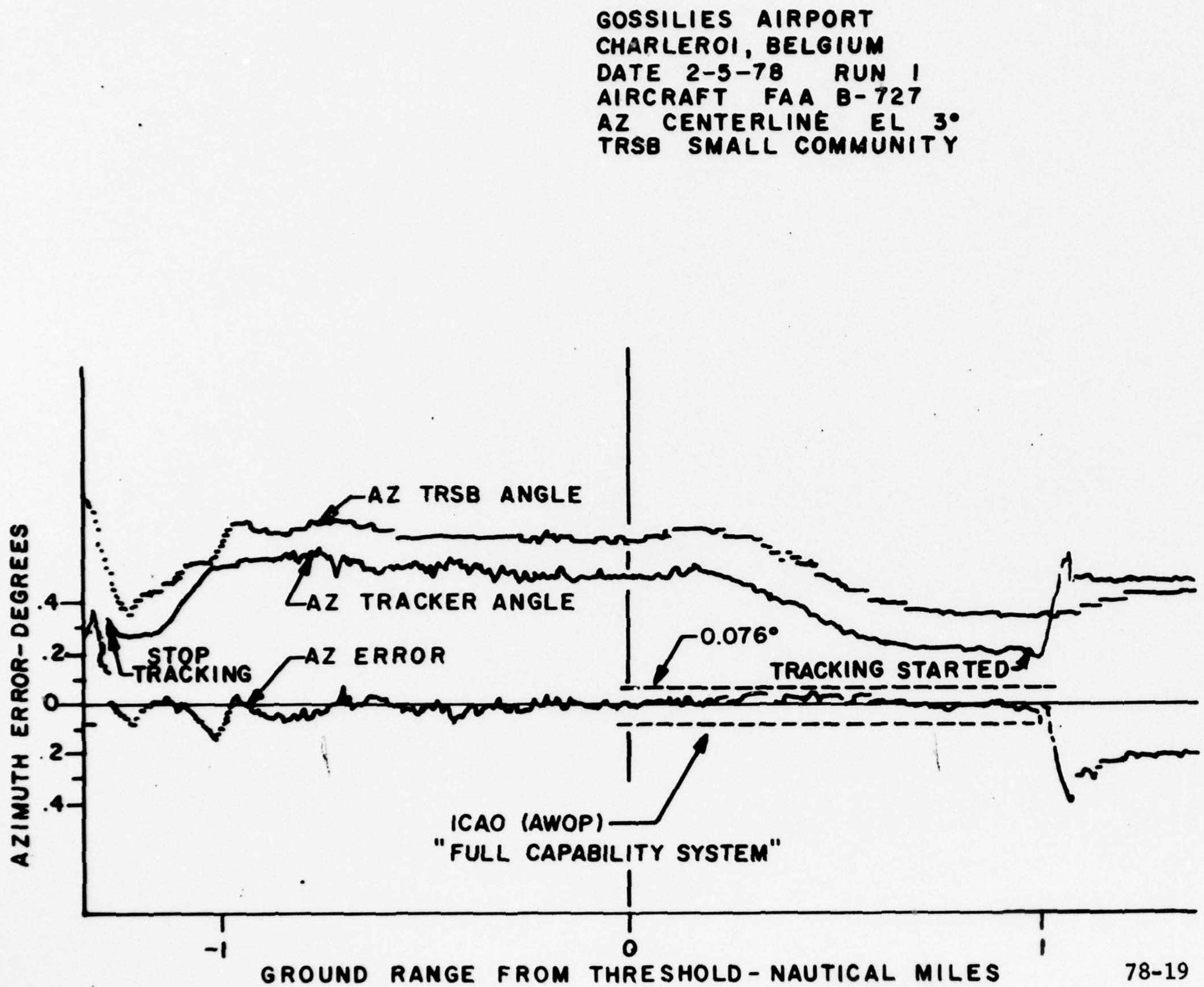


FIGURE 16. SAMPLE DATA PLOT FOR 3° CENTERLINE APPROACH

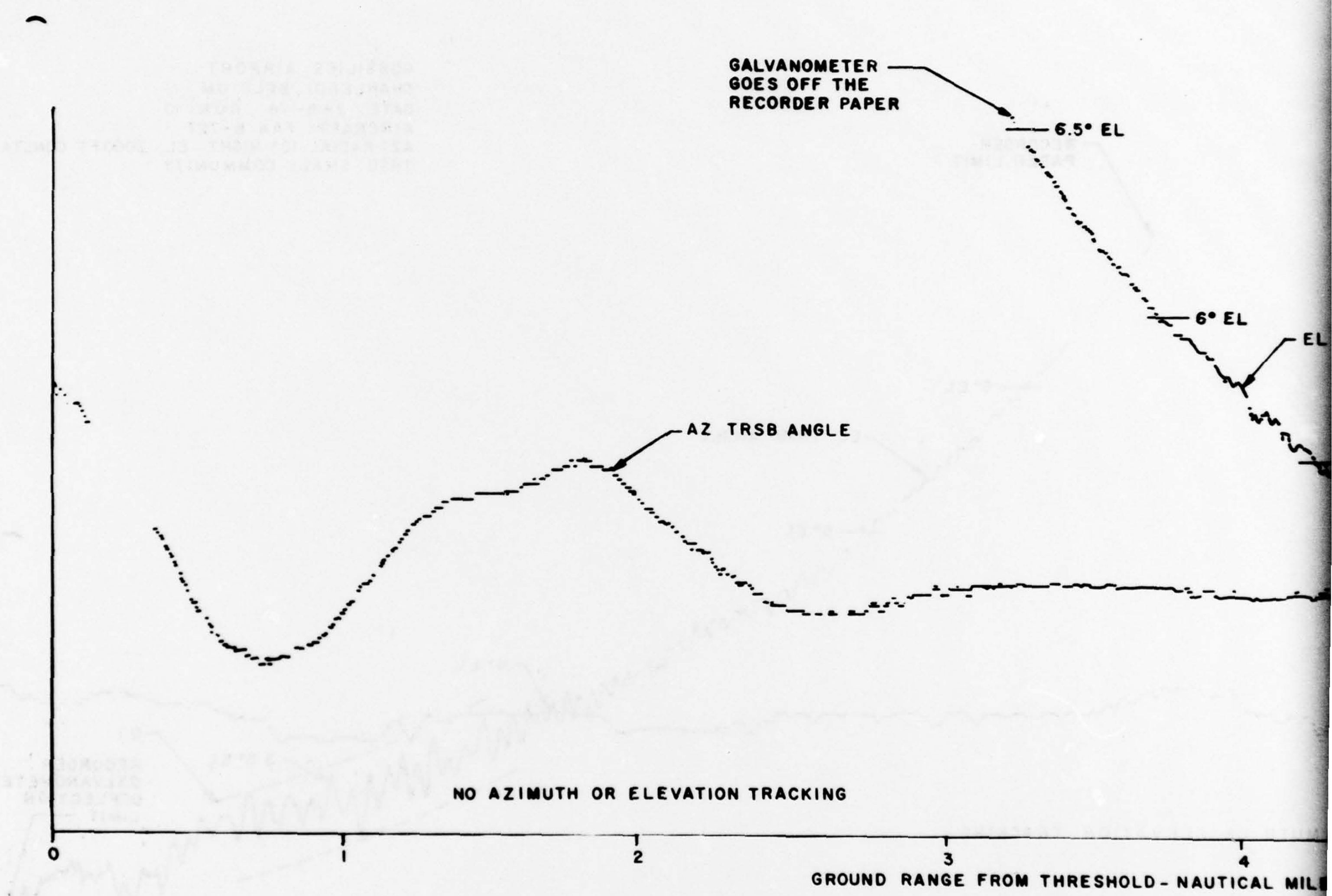
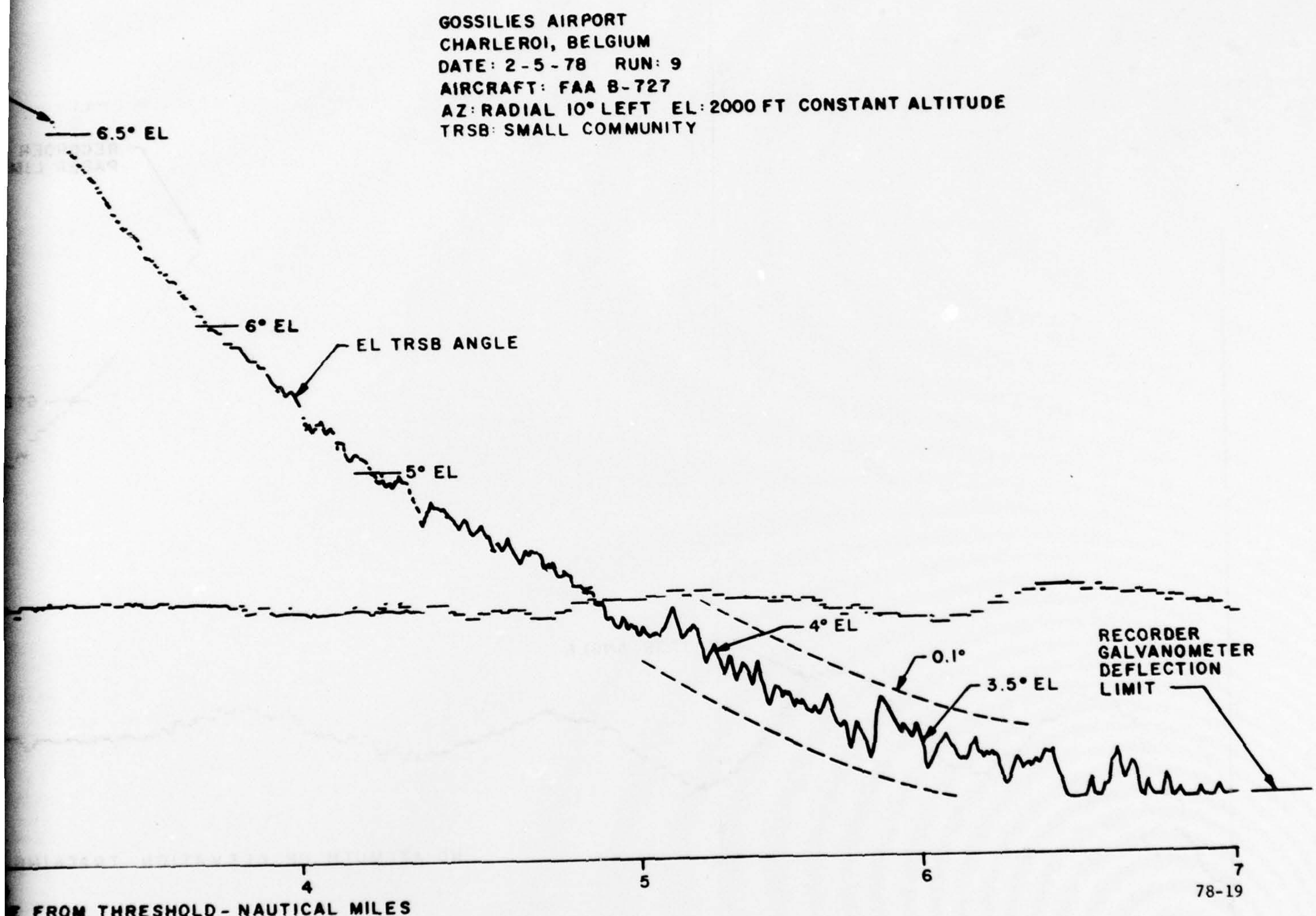


FIGURE 17. SAMPLE DATA PLOT FOR 2000-FOOT LEVEL 10° LEFT OF



R 2000-FOOT LEVEL 10° LEFT OF CENTERLINE RADIAL

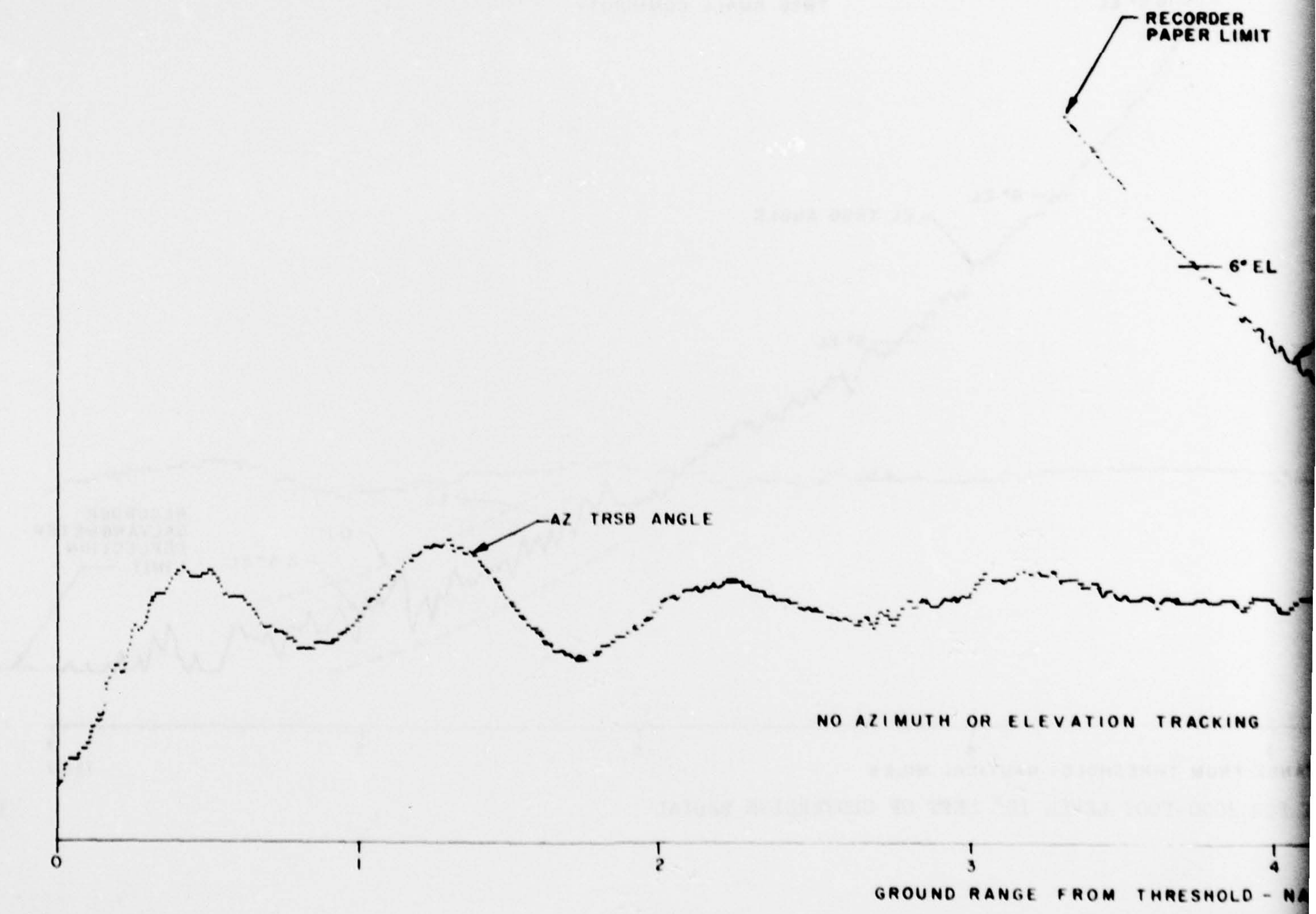
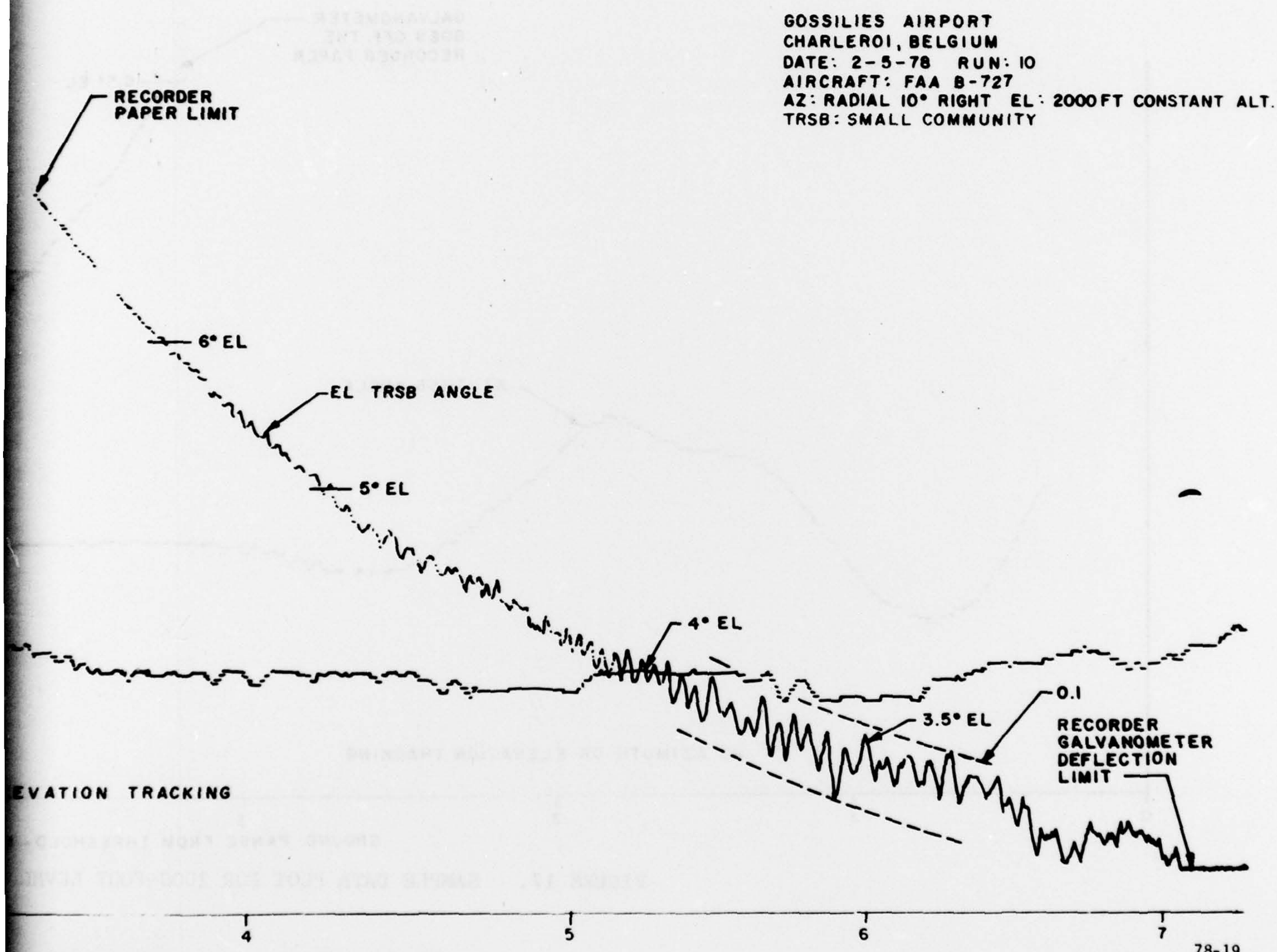


FIGURE 18. SAMPLE DATA PLOT FOR 2000-FOOT LEVEL 10°



FROM THRESHOLD - NAUTICAL MILES

R 2000-FOOT LEVEL 10° RIGHT OF CENTERLINE RADIAL

2

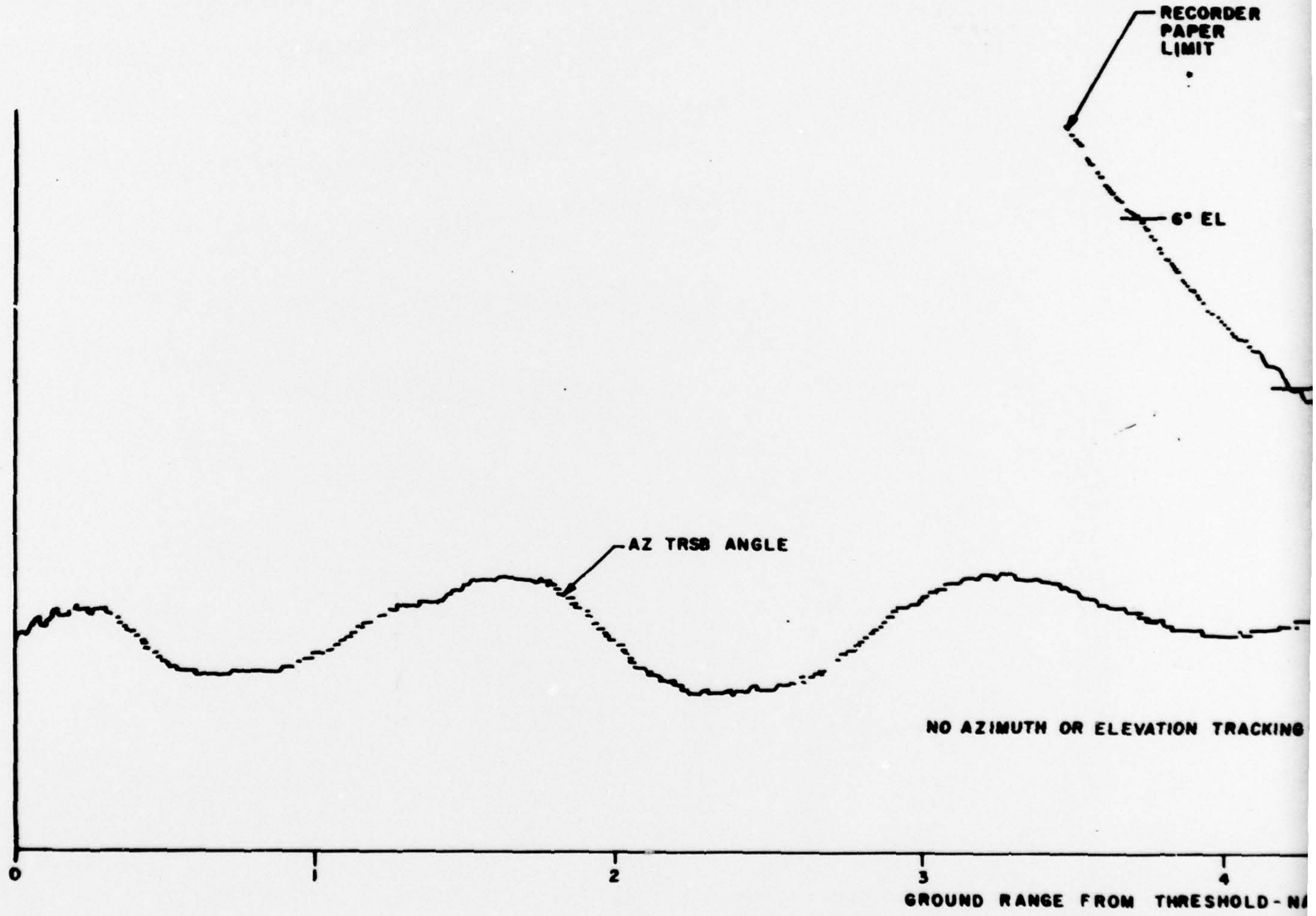
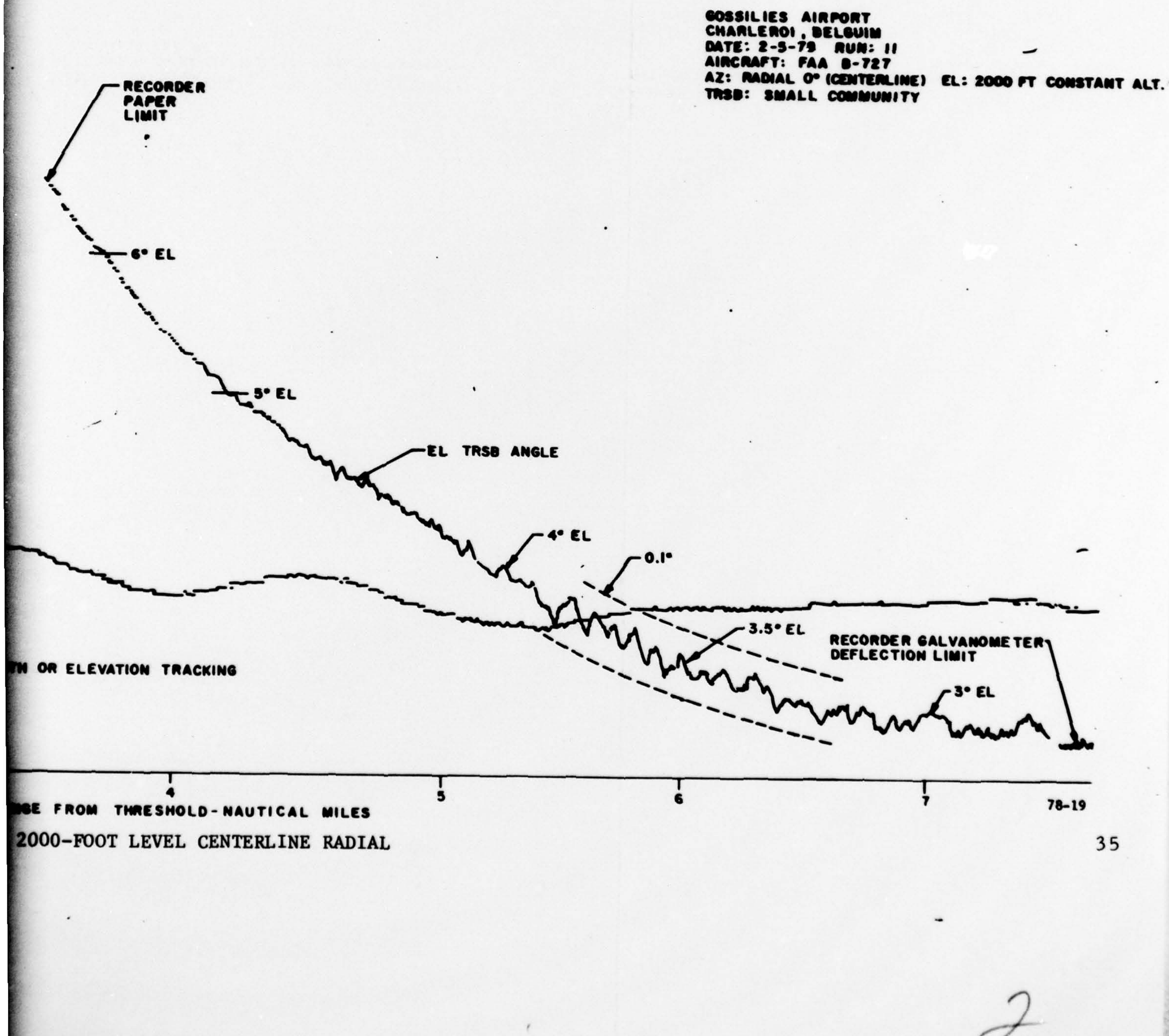


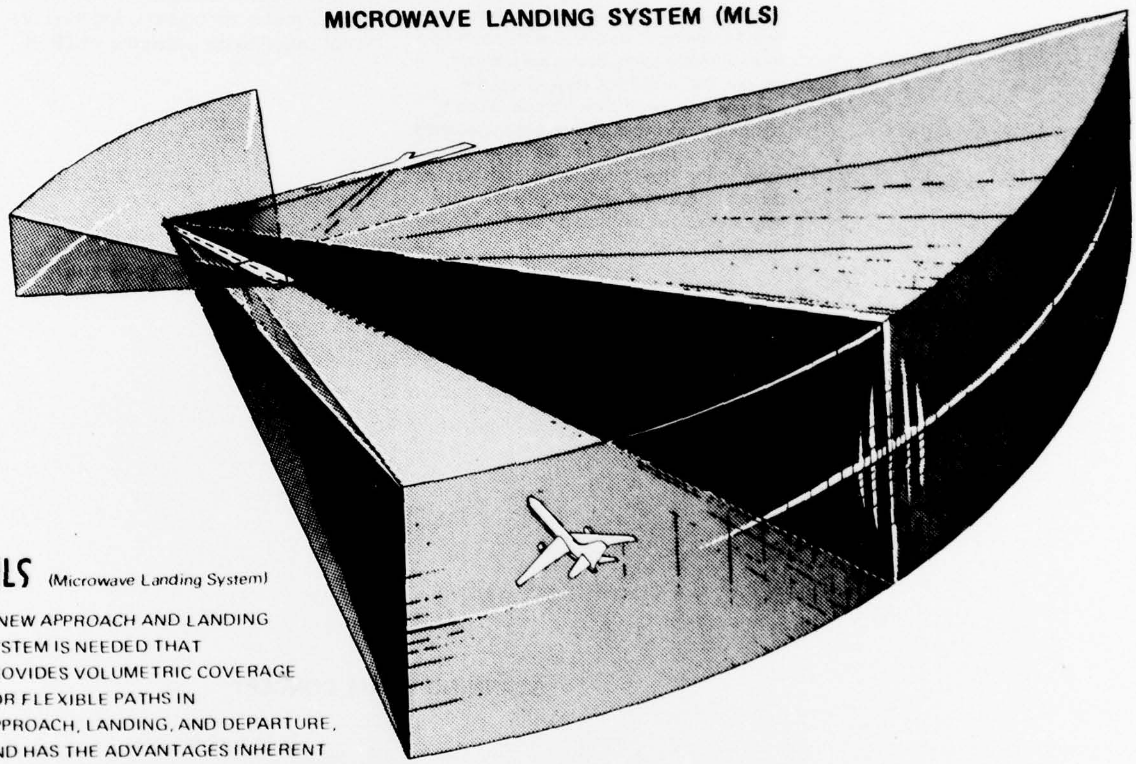
FIGURE 19. SAMPLE DATA PLOT FOR 2000-FOOT LEVEL CENT



2000-FOOT LEVEL CENTERLINE RADIAL

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

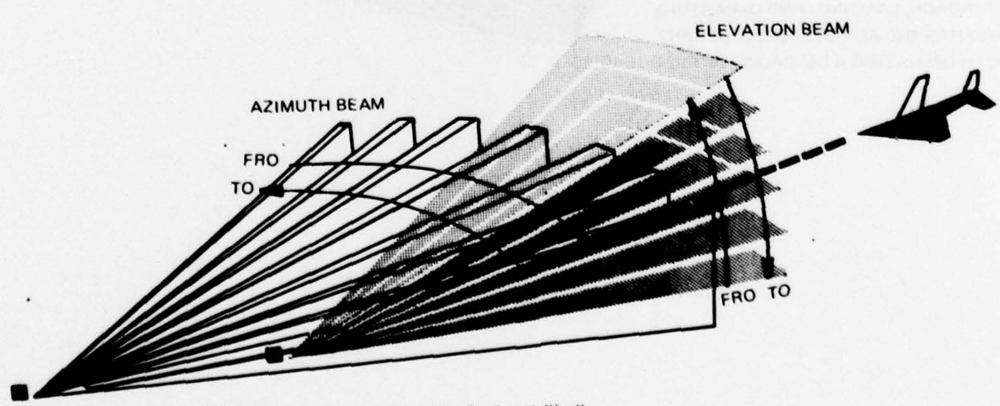
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data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



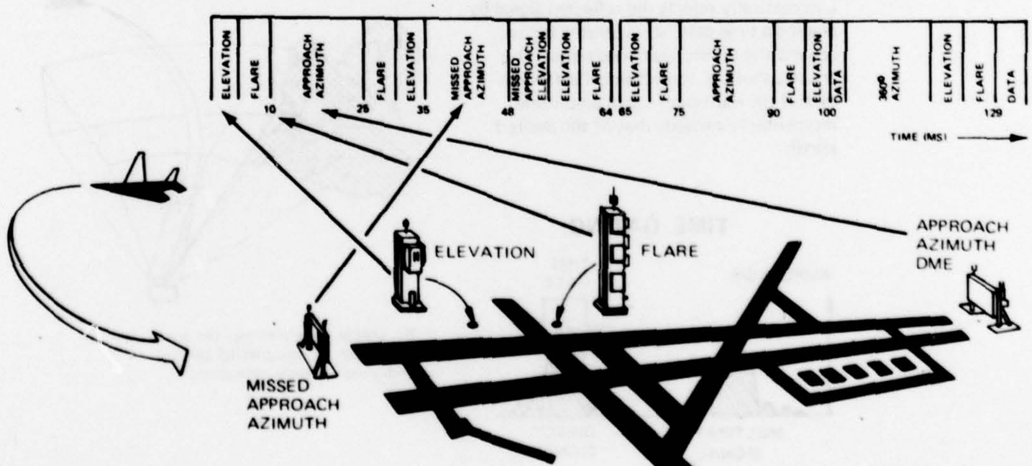
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

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.

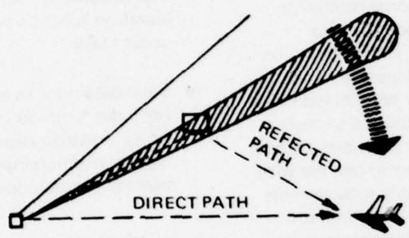


The TRSB signal offers maximum flexibility to meet unique user requirements

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.

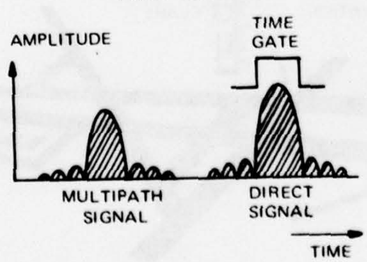
THERE ARE TWO TYPES OF MULTIPATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival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



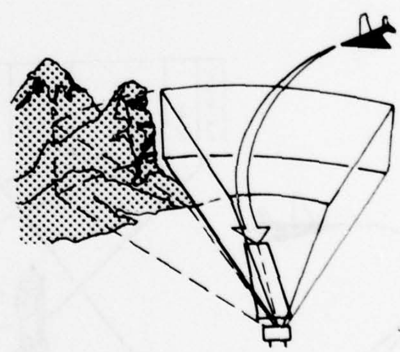
Time gating ensures that the correct signal is tracked, not the reflected one

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.

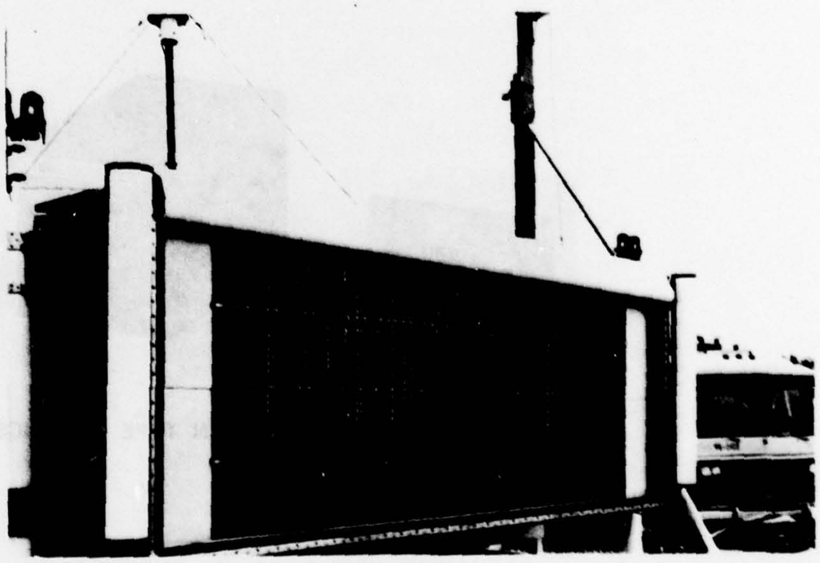
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide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



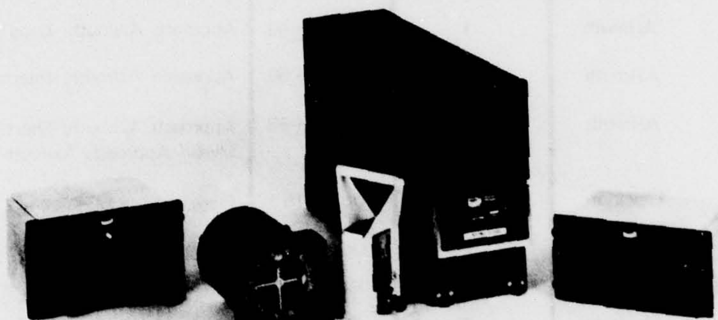
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

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.

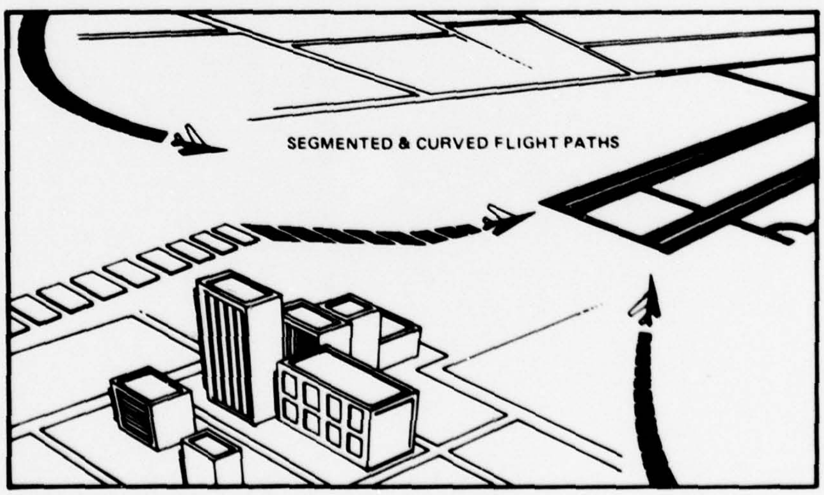
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

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