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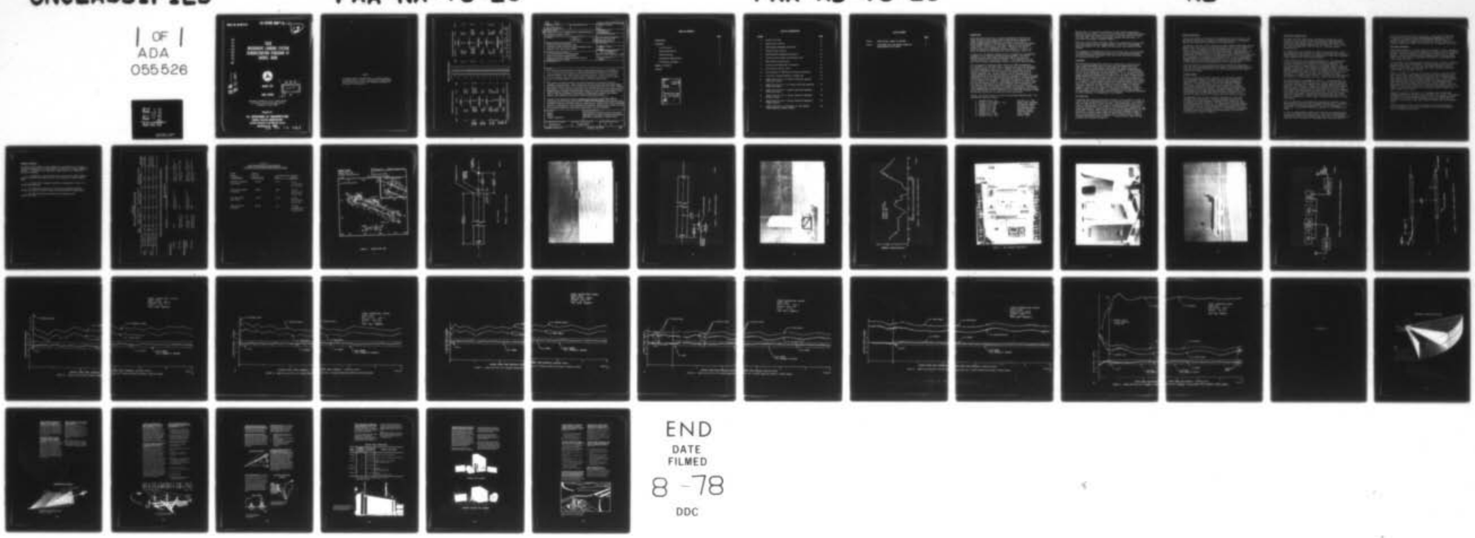

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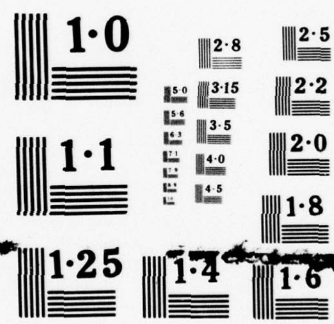

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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT SHIRAZ, IRAN

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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

NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

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

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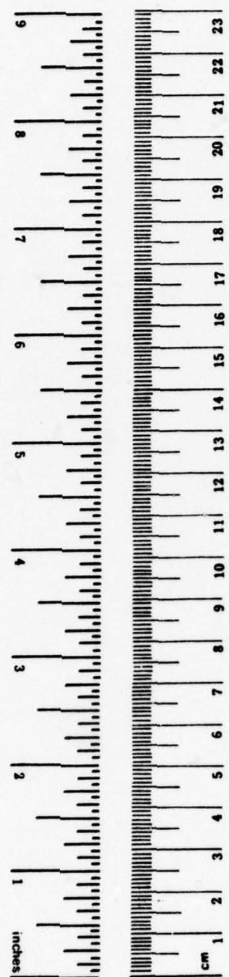
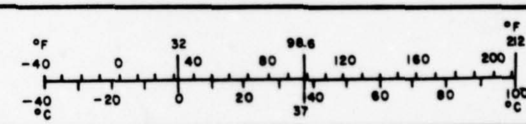


Approximate Conversions from Metric Measures

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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15. Supplementary Notes

16. Abstract

The operational demonstration at Shiraz International Airport serving Shiraz, Iran, was the tenth in a series of TRSB worldwide demonstrations. Previous demonstrations of the TRSB "Small Community System" which is representative of a simple, very economical system configuration, were held at six other sites in the United States, Central America, Europe, and Africa.

The system was flown to Shiraz in an FAA Boeing 727 testbed aircraft and installed on Runway 29R. Data acquisition and operational demonstration flights were flown with the FAA B-727 aircraft over the period March 3-8, 1978. During the flights, a radio telemetry theodolite was used for aircraft space-position data. Flight profiles included straight-in approaches at various elevation angles, level runs at 2000 feet altitude on centerline, and ±10-degree offsets, ±5-degree offsets, and 5-nautical mile partial orbits at 1500-feet altitude.

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Results of the flight tests indicate that the performance of the TRSB "Small Community System" was within the U.S. Phase III Program design requirements, the ICAO "reduced capability system" requirements, and the ICAO "full capability system" requirements. The feasibility of having one TRSB ground system serving two parallel runways by using offset approaches was demonstrated.

17. Key Words	18. Distribution Statement
Shiraz TRSB Small Community	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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Unclassified	Unclassified	34	

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and Australian (INTERSCAN) candidate submission to 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 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 hardware configurations at selected airports in the United States and abroad. (Hereafter for simplicity, "TRSB MLS" will be referred to as "TRSB.") These demonstrations are intended 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. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first hand knowledge of TRSB MLS and its applicability to their particular requirements.

Shiraz, Iran was the tenth in a series of operational demonstrations. The previous nine were as follows:

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, New York, USA
5.	January 23-24, 1978	Kristiansand, Norway
6.	February 1-3, 1978	Brussels, Belgium
7.	February 1-3, 1978	Charleroi, Belgium
8.	February 14-15, 1978	Dakar, Senegal
9.	February 23, 24, 1978	Nairobi, Kenya

Shiraz, Iran is a city with a population of about 500,000 located about 400 miles south of Tehran. The city is served by Shiraz International Airport which has two parallel runways 4,270 meters (14,009 feet) long by 45 meters (150 feet) wide. Iran Air is the principal operator serving Shiraz. A plan view of the airport is shown in Figure 1.

Runway 29L is the primary instrument runway and is equipped with an ILS, VASI, and a High Intensity Airport Lighting System. There are ILS and VOR/DME approach procedures for 29L. Runways 29L and 29R are also served by an NDB approach.

The topography in the immediate vicinity is relatively flat, but at distances of approximately 10-nautical miles the airport is surrounded by mountains which rise as high as 1524 meters (5,000 feet) above the airport elevation of 1498 meters (4,912 feet).

DISCUSSION

The TRSB system configuration selected for installation in Shiraz was the "Small Community System," which had previously been demonstrated at six other sites in the United States, Central America, Europe, and Africa. This equipment was manufactured by the Bendix Corporation's Communications Division in accordance with FAA specifications (Table 1). It is representative of the most economical system configuration. It was designed to provide azimuth proportional guidance over an area of plus and minus 10 degrees about runway centerline with directional guidance (i.e., fly left or right from 10 degrees out to 40 degrees on either side of the runway centerline similar to an ILS localizer). The elevation proportional guidance extends from 2 degrees to 15 degrees. System coverage distance is at least 20-nautical miles under heavy rain conditions and much greater under less stringent environmental conditions. Basically, the small community TRSB was designed to provide Category I service on most runways in most airport environments. Guidance quality, however, has been shown to be considerably better than Category I ILS requirements and will support autoland operations. Descriptive information on TRSB is presented in the Appendix to this document.

Site Selection

A three-man team from the FAA arrived in Tehran, Iran on January 16, 1978, to conduct initial discussions with Iran civil aviation officials. On January 18, 1978, the team arrived in Shiraz and spent 2 days conducting a survey of the airport, selecting exact site locations, conducting discussions with local officials, and attending to the details of the installation, presentation, and flight demonstration. Runway 29R was selected for the installation of the TRSB MLS system. The exact site location for the azimuth subsystem is shown in Figure 2 and a typical azimuth subsystem installation is shown in Figure 3. The elevation subsystem site location is shown in Figure 4 while a typical elevation subsystem is shown in Figure 5. A terrain profile taken from the elevation site is shown in Figure 6.

System Installation

Prior to the arrival of the aircraft and demonstration team in Shiraz, a two-man advance team arrived in Shiraz to confirm and finalize all arrangements made for the installation, presentation, and demonstration.

The aircraft, FAA N-40, a B-727 carrying the Small Community TRSB System and the demonstration team, arrived at Shiraz International Airport on the evening of March 1, 1978. Unloading of the aircraft began at 0900 on March 2 after customs clearance was granted by the Iranian Government. The unloading of the aircraft was accomplished with a large fork lift and was completed by 1015. A medium duty flat bed truck, with a crane mounted near the front of the bed, was used to transport the equipment to the respective sites. All of the equipment was transported to the appropriate locations by 1100. Metal platforms were assembled and used as mounting foundations instead of poured concrete because of time limitations and the temporary nature of the installations.

Power was applied to both subsystems and both subsystems were radiating by 1530. By 1830, both subsystems had been checked. The total elapsed time from the start of unloading the aircraft until both subsystems were fully operational was 9.5 hours.

Airborne System

The B-727 airborne TRSB system consisted of the following equipment: dual TRSB angle receivers, dual angle receiver control heads, dual course deviation indicators, and dual precision DME interrogators (Figure 7). The analog outputs of one of the TRSB angle receivers were routed to the cockpit where they could be selected to drive a Collins Radio Company FD-109 Flight Director System or the approach coupler of a Sperry SP-50 autopilot. Raw analog deviations could also be presented on the cockpit Horizontal Situation Indicator (HSI). The analog outputs of the TRSB angle receivers were not filtered in any way and the Flight Director and Autopilot were not modified in any way.

Instrumentation used for data acquisition consisted of a strip chart recorder, time code generator, a modified UHF glide slope receiver for reception of radio telemetric theodolite (RTT) information, and a differential amplifier (Figure 8). The TRSB receiver which was used to provide outputs to the data collection system and to the flight director and autopilot utilized an omni directional antenna mounted on the top, forward part of the test aircraft (Figure 9). A simplified block diagram of flight control and instrumentation interconnection with the TRSB angle receiver is shown in Figure 10.

Operational Demonstrations

The TRSB operational demonstration briefings and flights were held on March 6, 7, and 8 1978. Sixty-six participants registered and 63 flew on the flight demonstrations. Representatives were present from the Iranian Civil Aviation Organization, the Iranian Air Force, The U.S. Air Force, the Embassies of the U.S. and U.K., and some industry representatives.

Each demonstration was preceded by a TRSB MLS program briefing. After the program briefing, the group was bussed to the airport and divided into smaller groups to participate in the demonstration flight and a simultaneously conducted tour of the ground equipment.

An FAA B-727 was used for all flight demonstrations. The flight demonstration consisted of three approaches selected to demonstrate the flexibiity and accuracy of a simple, very economical TRSB MLS. The first approach was a 4-degree elevation, zero-degree azimuth (centerline) approach to runway 29R. This approach was conducted using the autopilot approach coupler down to an altitude of 61 meters (200 feet). On the first day of demonstrations (March 6, 1978), this approach was started at an altitude of 7,012 meters (23,000 feet) and a distance of 60 nmi to demonstrate the usable range of TRSB MLS. This autopilot coupled approach was flawless to a manual takeover at the 61 meter (200 feet) altitude.

The second approach is diagrammed in Figure 11. In this approach, the TRSB installation on Runway 29R was used to provide precision elevation and azimuth guidance to the demonstration aircraft making an approach to Runway 29L. By selecting a 5-degree, left azimuth offset and a 3-degree elevation angle, a minimum decision altitude (MDA) of 61 meters (200 feet) placed the aircraft about 914 meters (3000 feet) prior to threshold and slightly left of extended runway centerline. At this point, the pilot went visual and executed a course correction to the left for a visual approach to runway 29L. Operationally, the NAFEC flight test pilots on board the demonstration aircraft judged the approach procedure to be very satisfactory.

The third approach of the demonstration sequence was conducted on zero degree azimuth (centerline) and a 3-degree elevation angle. The approach was manually flown and was terminated with a full stop landing on runway 29R. This approach sequence was repeated for each demonstration flight.

A total of 5 demonstration flights were flown over the three-day period. On the second demonstration day, March 7, 1978, the area around Shiraz International Airport was covered by heavy rain cells. The technicians on board the aircraft reported the TRSB signals were strong and solid at least to 25 nmi from the field in heavy rain. During the second approach on the second day, the aircraft wing was struck by lightning. There was no effect on the TRSB MLS signals and the approach was continued to a landing, but additional flights were cancelled for the day. When the aircraft was examined for damage, only a burned static discharge wick was found.

Performance Assessment

Ground based tracking for the TRSB flights was provided by a radio telemetric theodolite (RTT) used alternately at azimuth or elevation sites as requirements dictated. The RTT is a manually operated optical tracker used to transmit azimuth or elevation angle positon data (depending upon its siting for the flight) to the aircraft via a transmitter operating on an unused UHF glide slope channel (329.0 MHz).

In the aircraft, the received analog tracker angle data, azimuth or elevation, was subtracted from the TRSB azimuth or elevation angle data to provide a measure of system error. In each case, the angle difference as well as tracker angle and TRSB angle were recorded on light sensitive strip chart recorder paper on an analog recorder.

Figures 12 through 17, inclusive, are copies of airborne strip chart recordings from six runs; three tracked azimuth runs and three tracked elevation runs. Each of these figures contains a reproduced trace of tracker angle, TRSB receiver angle, and the difference between the two. In the error plots, small alignment bias errors have been removed. The longitudinal axis of these plots represents range from Runway 29R threshold determined from event marks and the field DME, which is located in the center of the field between the two parallel runways and 1.5 nmi from Runway 29R threshold. ICAO (AWOP) total error limits for the "full capability system" (Table 2) have been included on the figures.

Referring to Figures 12 through 17, it is apparent that the TRSB Small Community System errors are within the ICAO (AWOP) error limits of ± 0.1 degree in elevation and ± 0.076 degree in azimuth for the "full capability system." In Figure 17, the trace for TRSB elevation angle is included to show the quality of the elevation signal when flying a 5-degree, left offset azimuth radial.

System coverage was checked during clockwise (CW) and counterclockwise (CCW) 5-nmi partial orbits flown at 457 meters (1,500 feet) altitude and met the coverage specifications.

SUMMARY OF RESULTS

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

1. Performance of the TRSB system was within both the ICAO "reduced capability system" requirements and the "full capability system" requirements.

2. The TRSB "Small Community System" was demonstrated to meet its design specifications.

3. The operational feasibility of having one TRSB ground system serving two parallel runways by using offset approaches was demonstrated.

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	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
ICAO (AWOP) FULL AND REDUCED
CAPABILITY CONFIGURATION ERROR LIMITS

AWOP System Configuration	Distance to Error Window (Feet)	Permitted Error (2 Sigma) Feet	Permitted Error (2 Sigma) 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

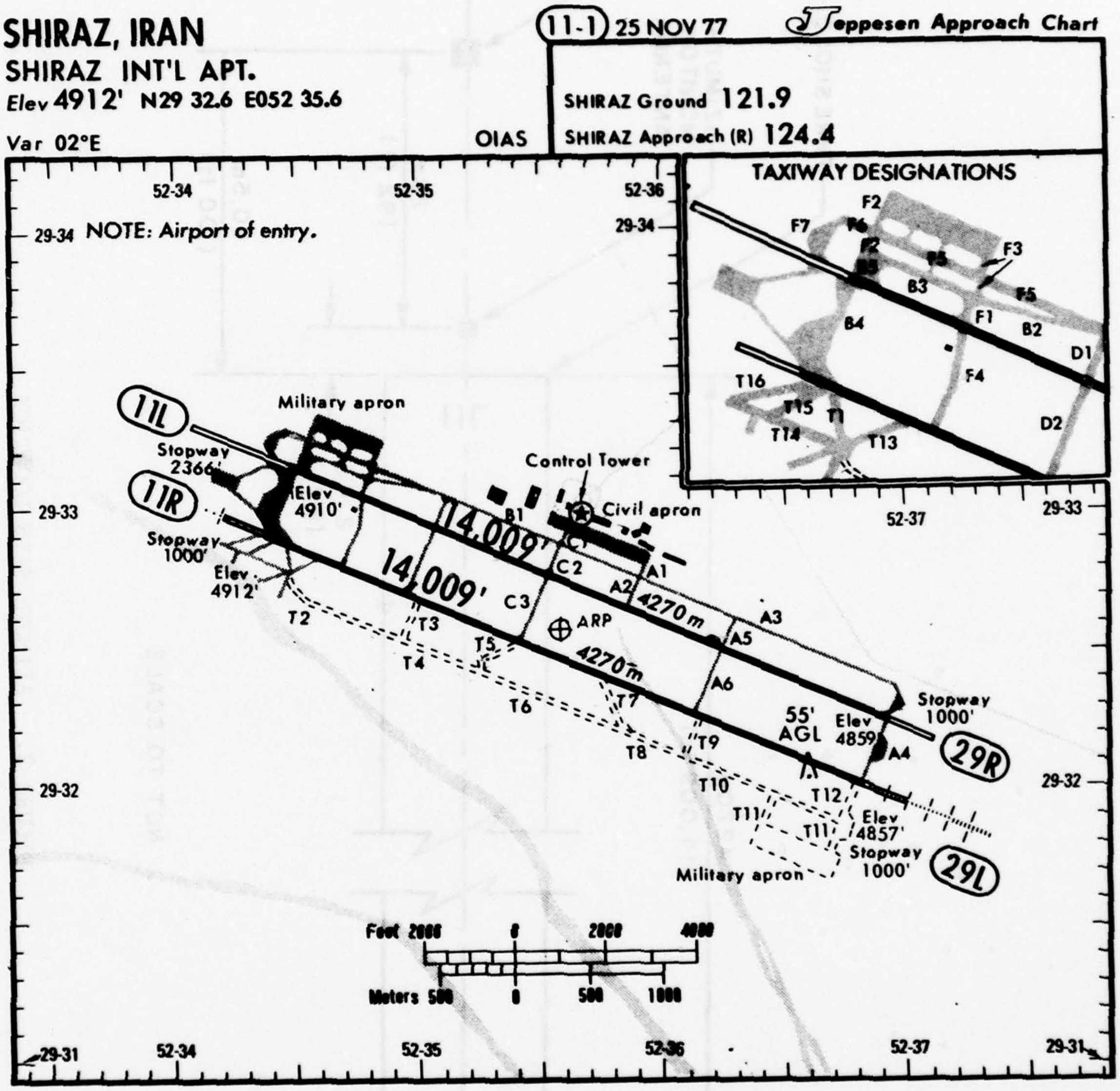

FIGURE 1. AIRPORT PLAN VIEW

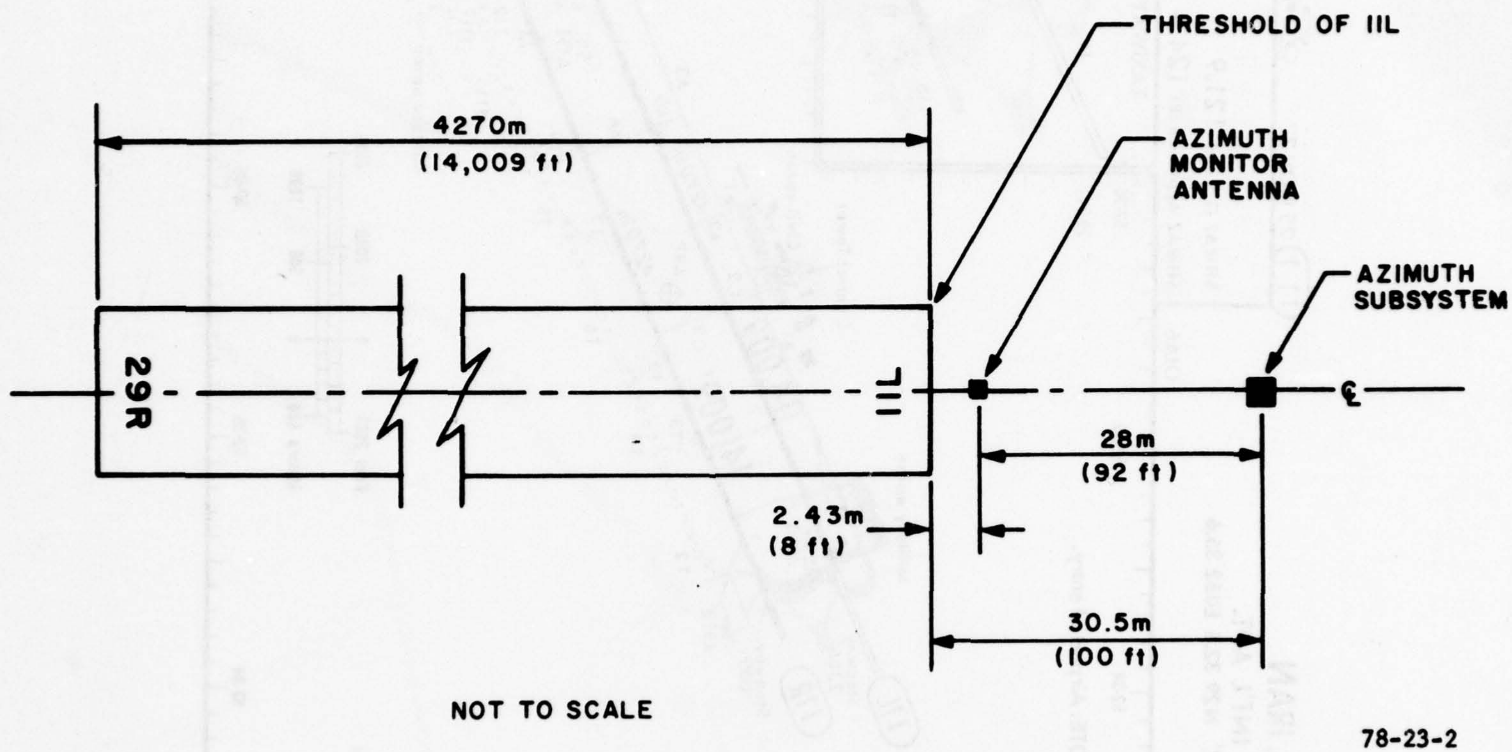

FIGURE 2. AZIMUTH SITE LOCATION

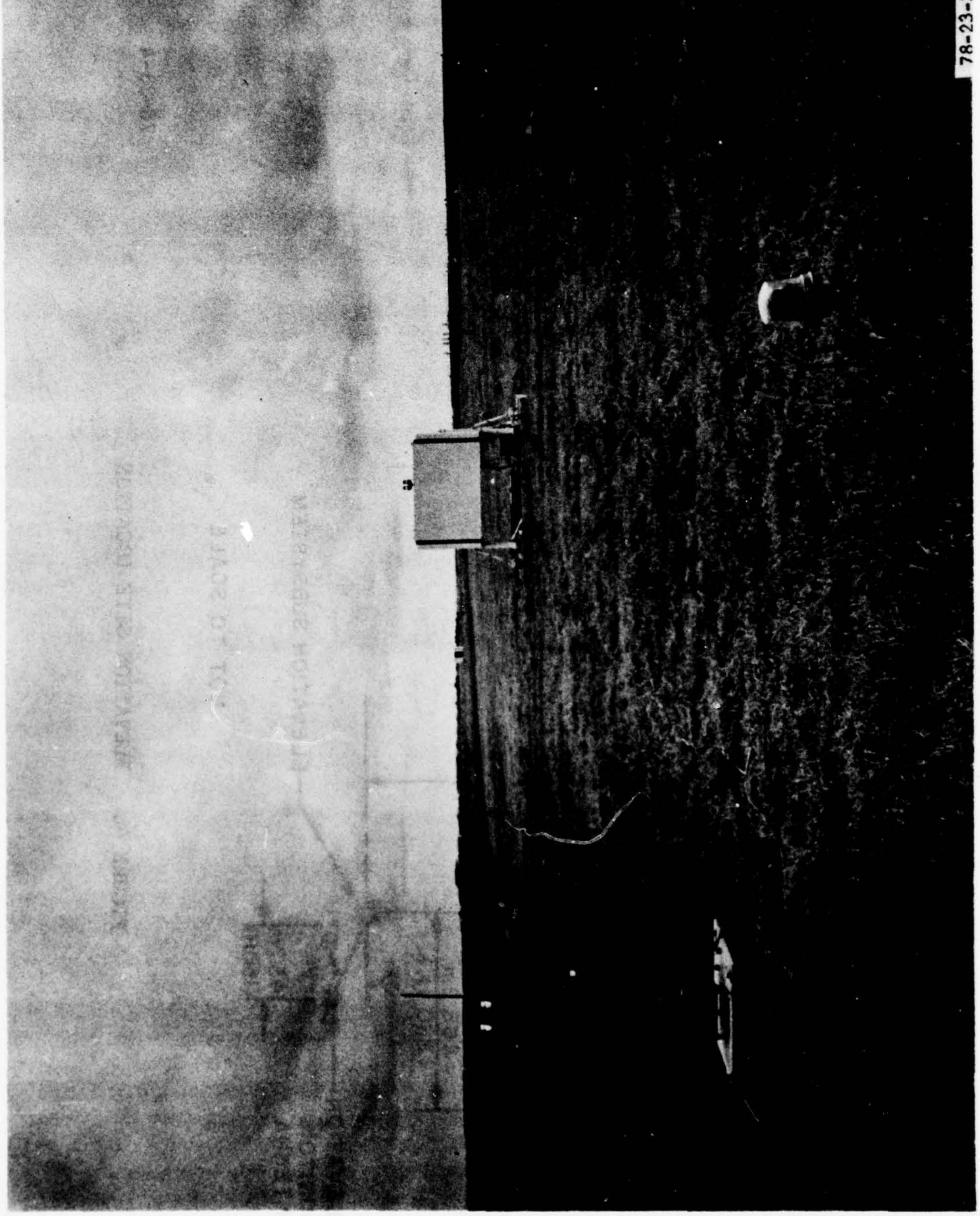

FIGURE 3. TRSB AZIMUTH SUBSYSTEM AND MONITOR

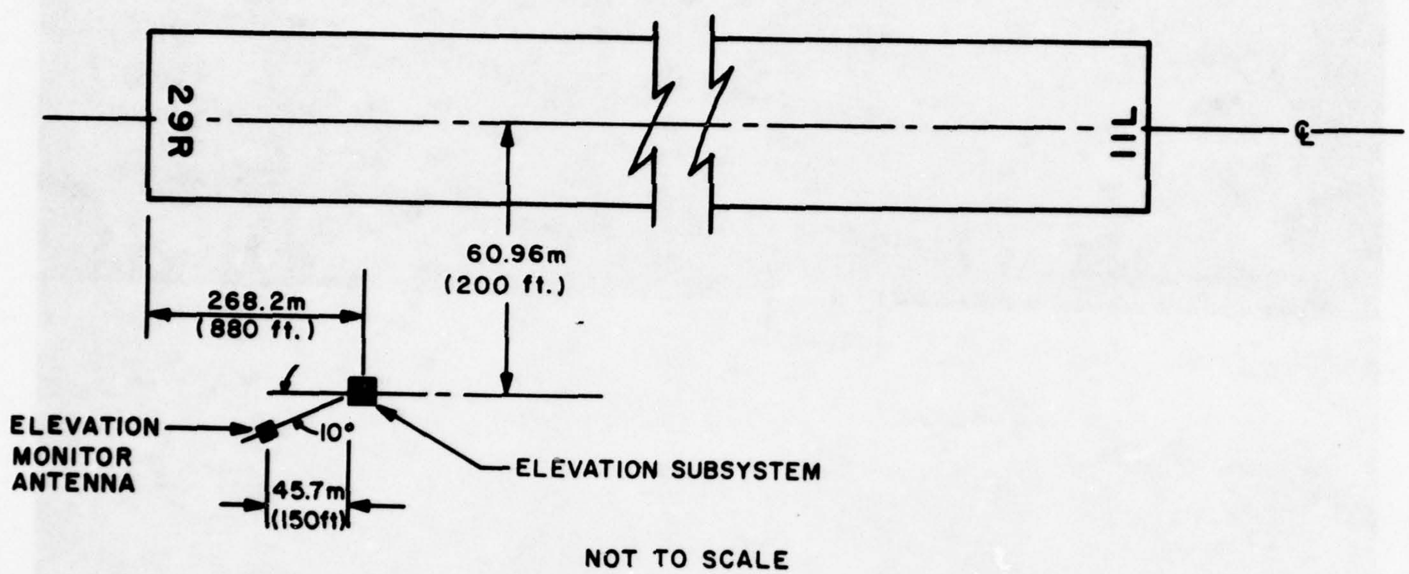

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FIGURE 4. ELEVATION SITE LOCATION

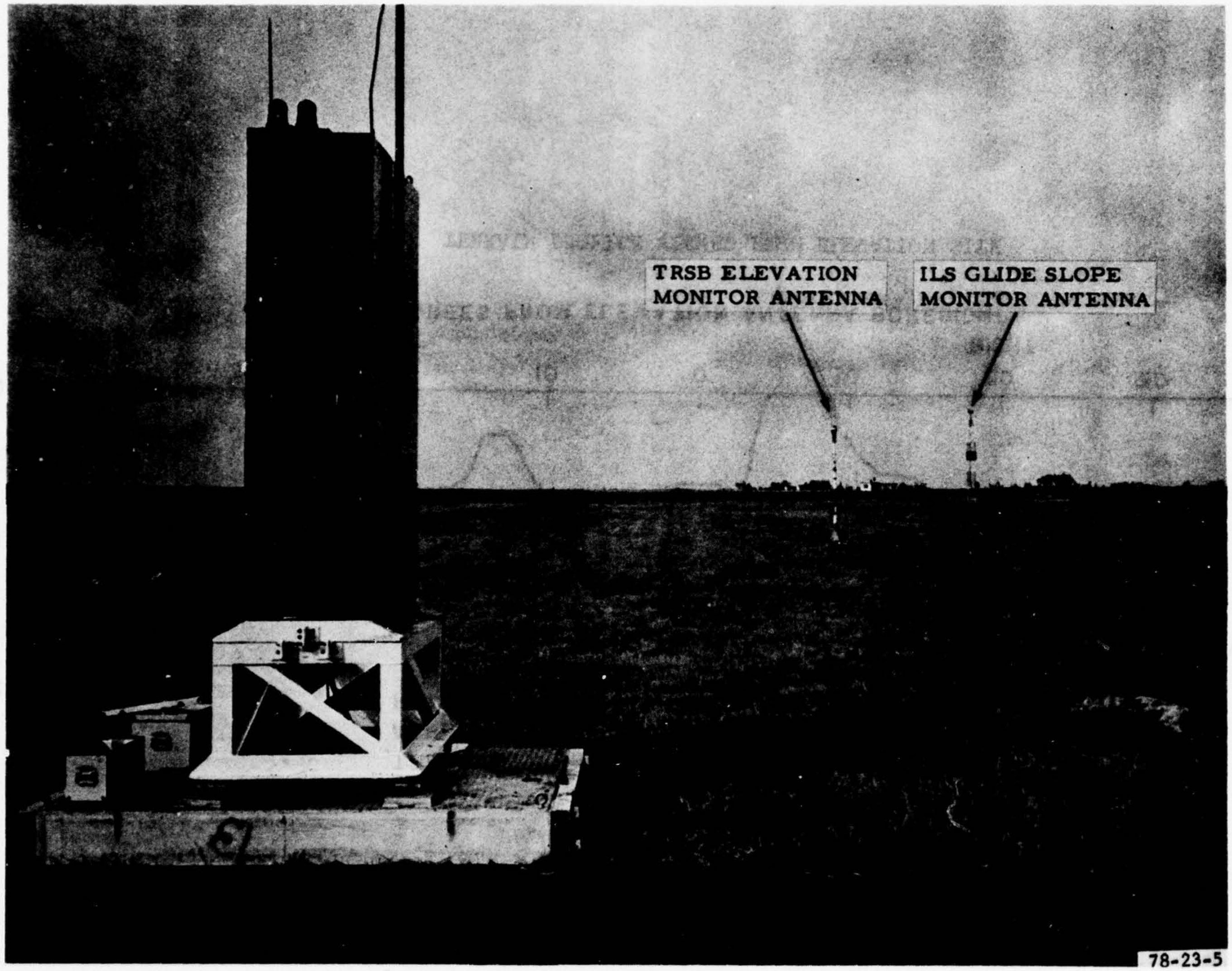

FIGURE 5.   TRSB ELEVATION SUBSYSTEM AND MONITOR

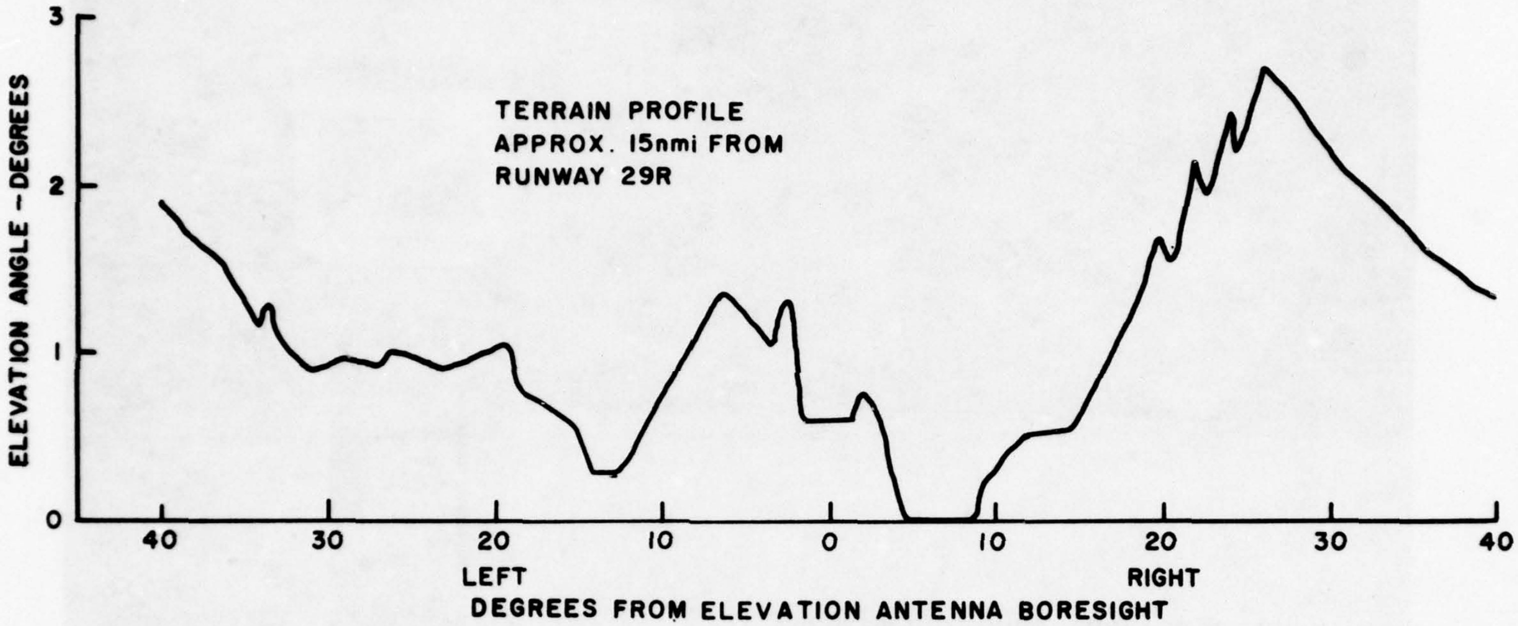

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FIGURE 6. TERRAIN PROFILE VIEWED FROM ELEVATION SITE

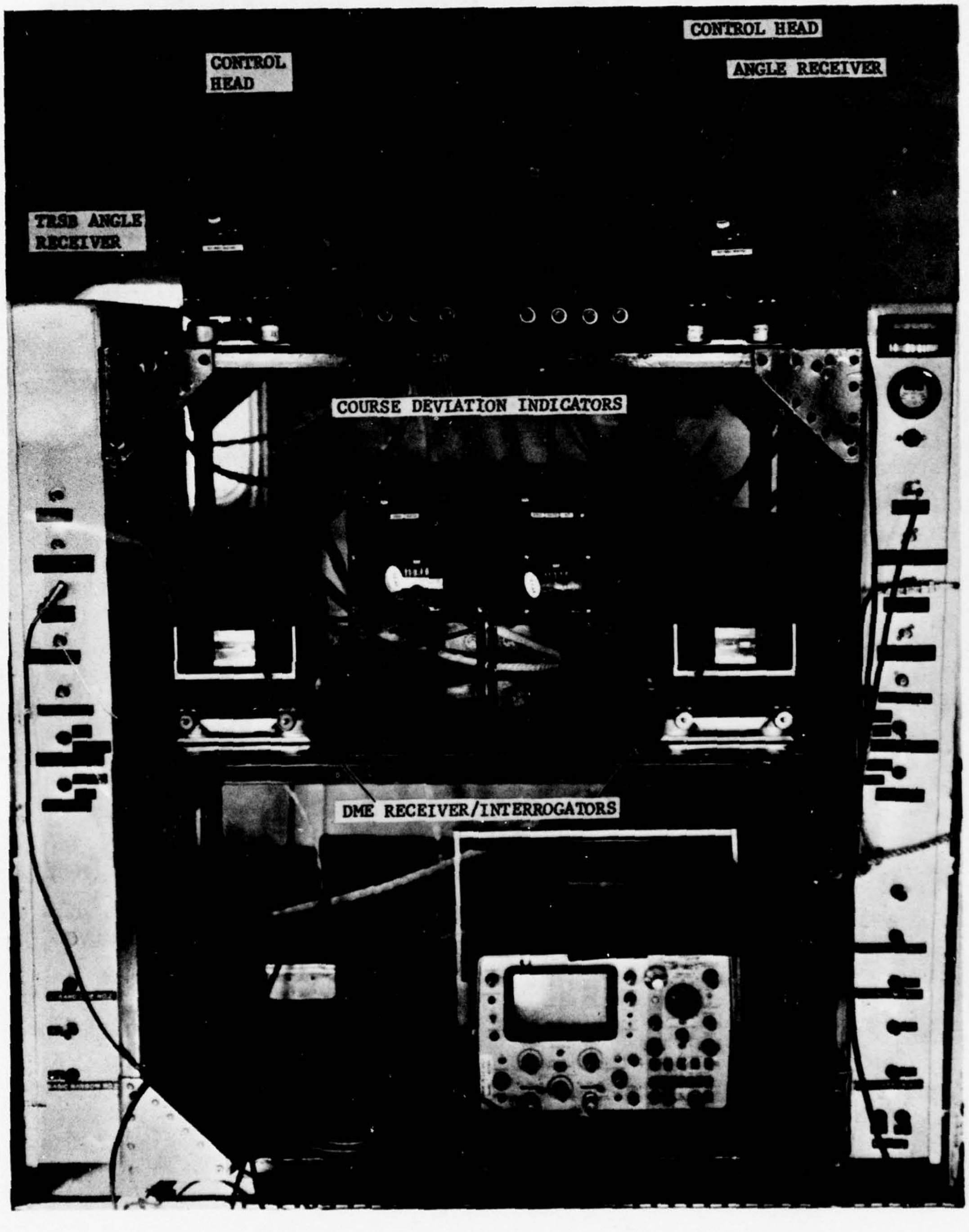


FIGURE 7. TRSB AIRBORNE INSTALLATION

FIGURE 8. AIRBORNE INSTRUMENTATION INSTALLATION

FIGURE 9. FAA TESTBED AIRCRAFT (N-40)

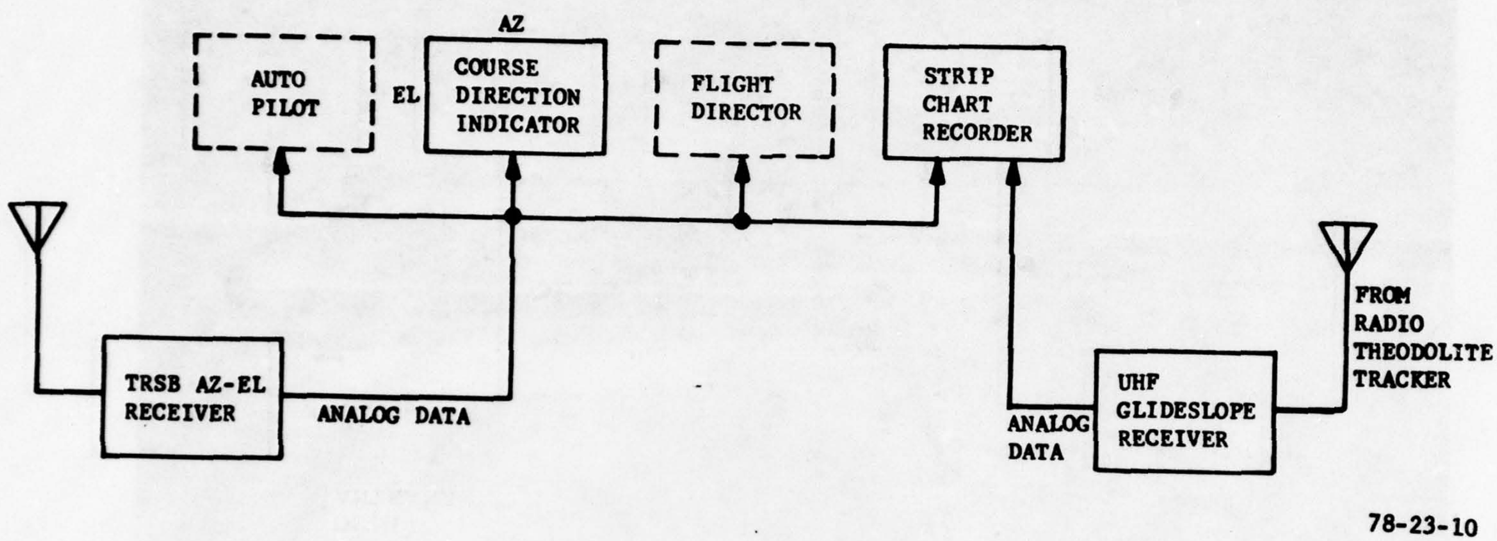


FIGURE 10. BLOCK DIAGRAM OF TRSB-AIRCRAFT SYSTEMS INTERCONNECT

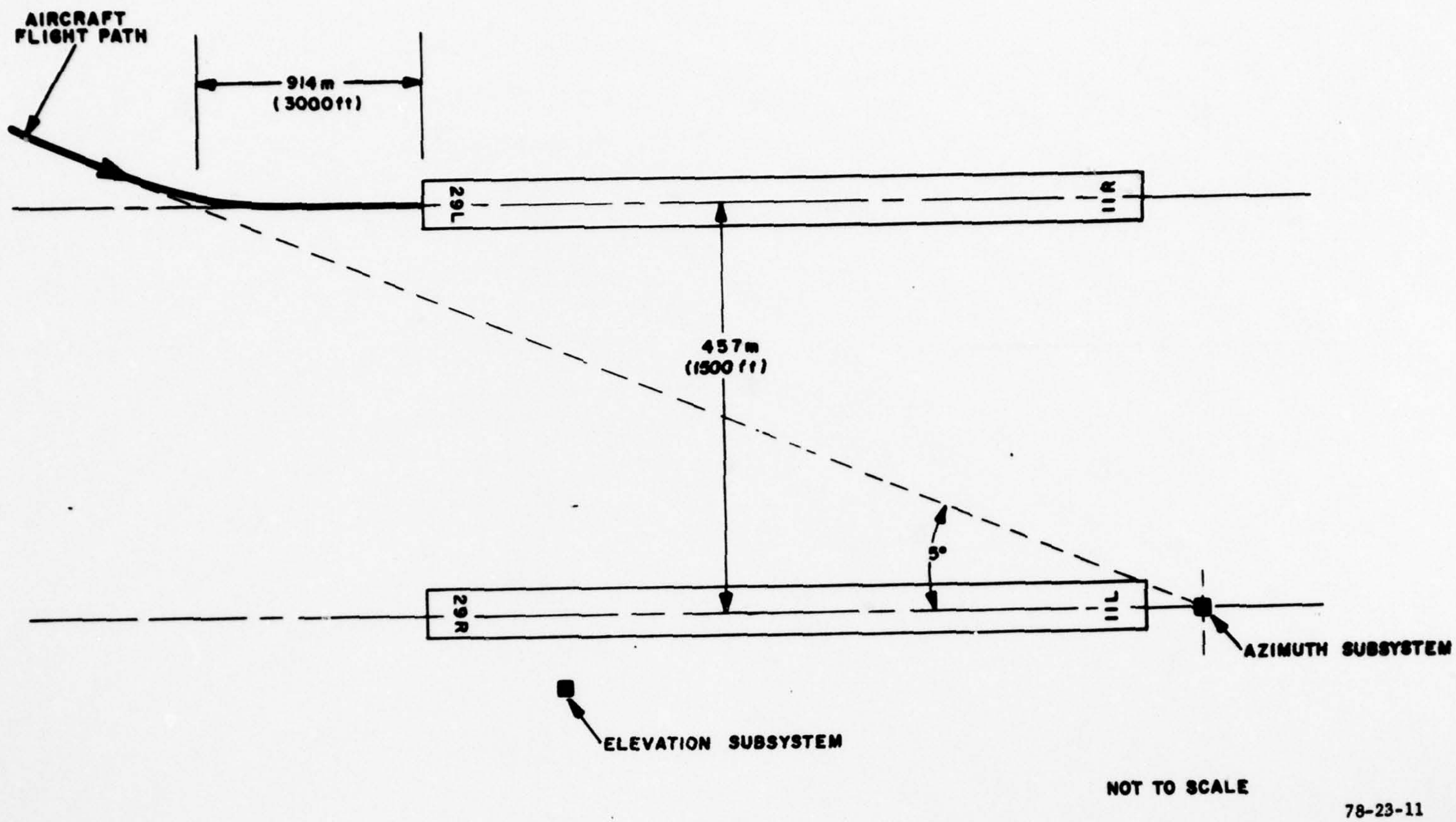


FIGURE 11. PICTORIAL OF OFFSET APPROACH TO RUNWAY 29L

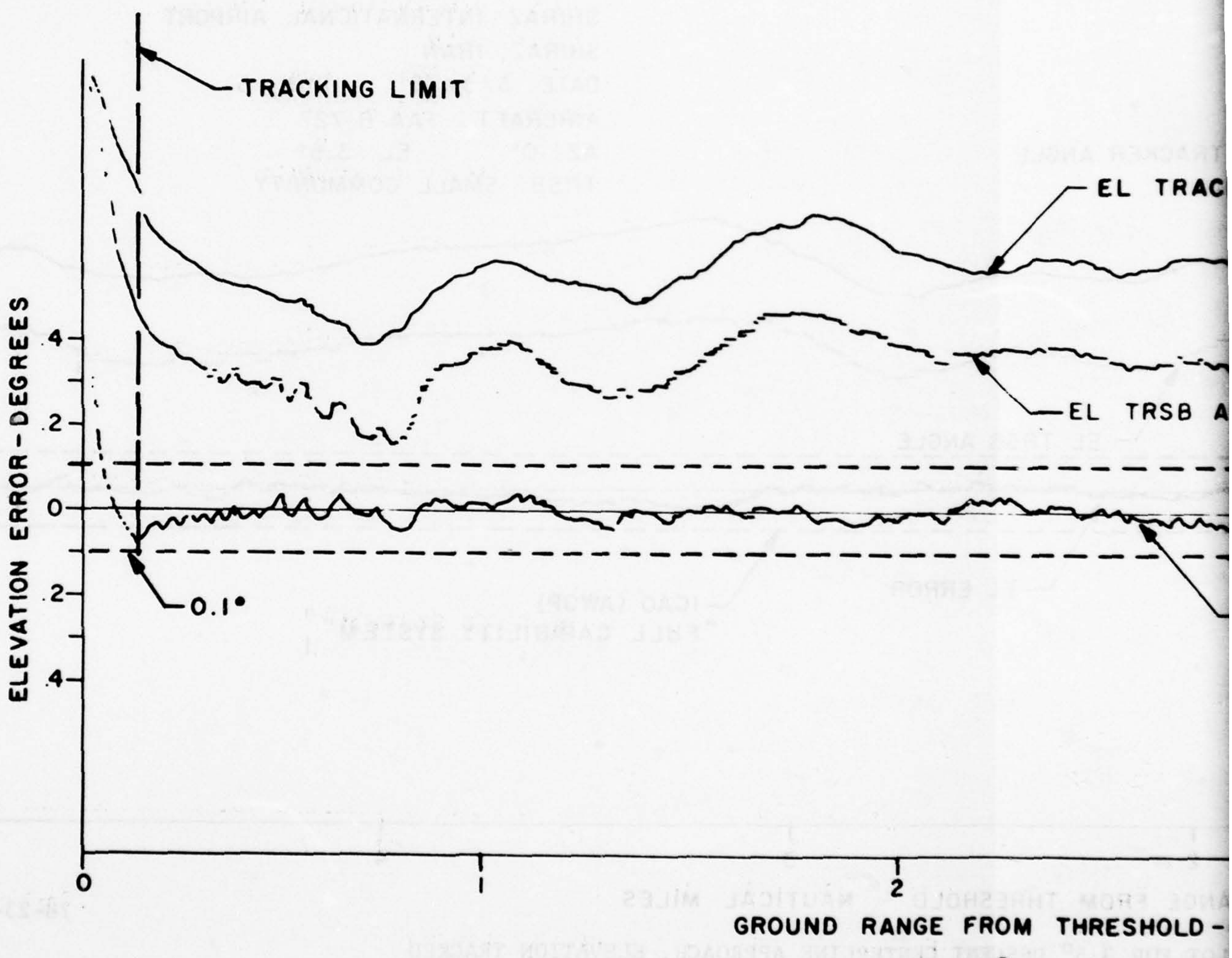
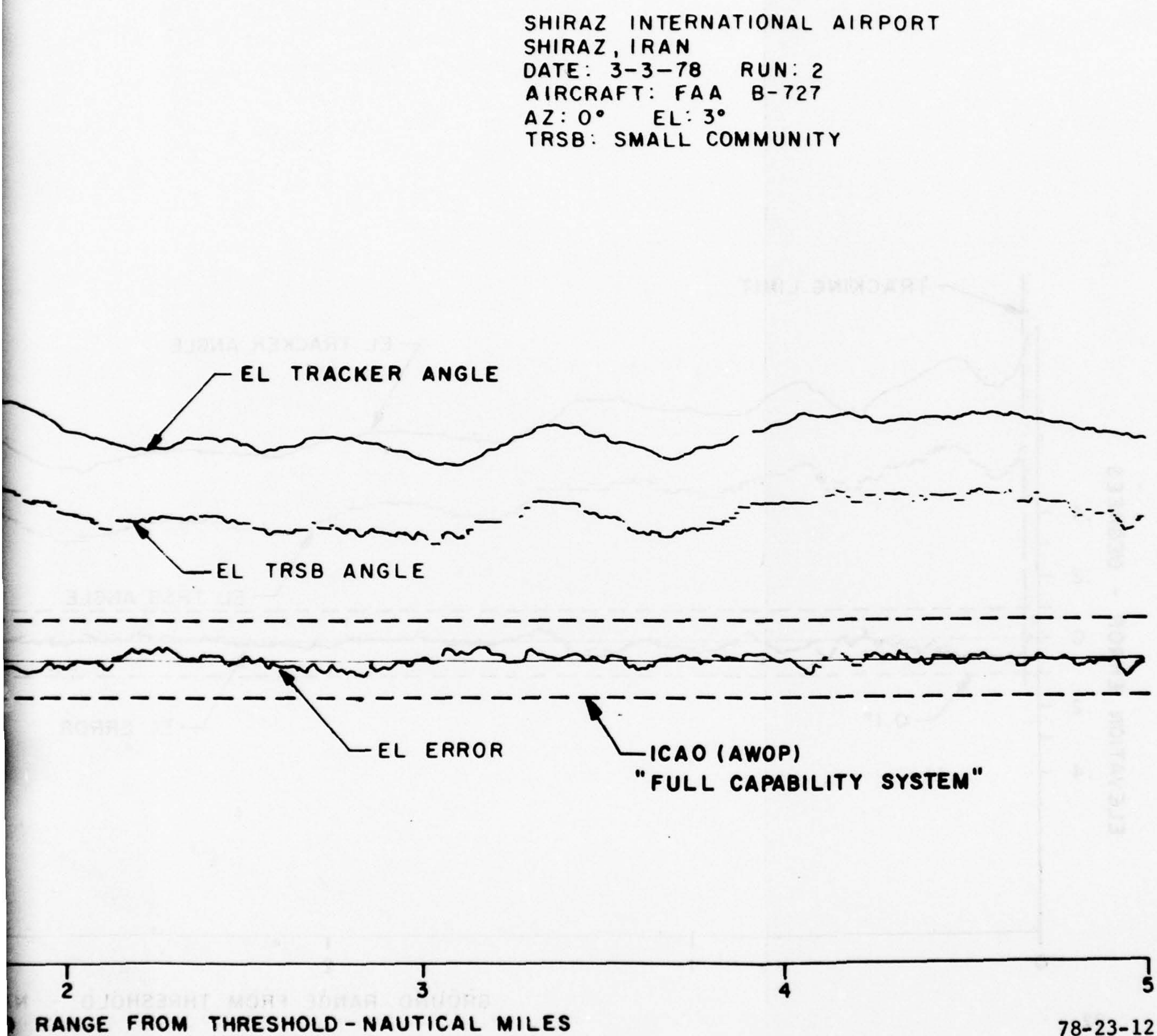


FIGURE 12. SAMPLE DATA PLOT FOR 3° DESCENT CENTERI



A PLOT FOR 3^{O} DESCENT CENTERLINE APPROACH, ELEVATION TRACKED

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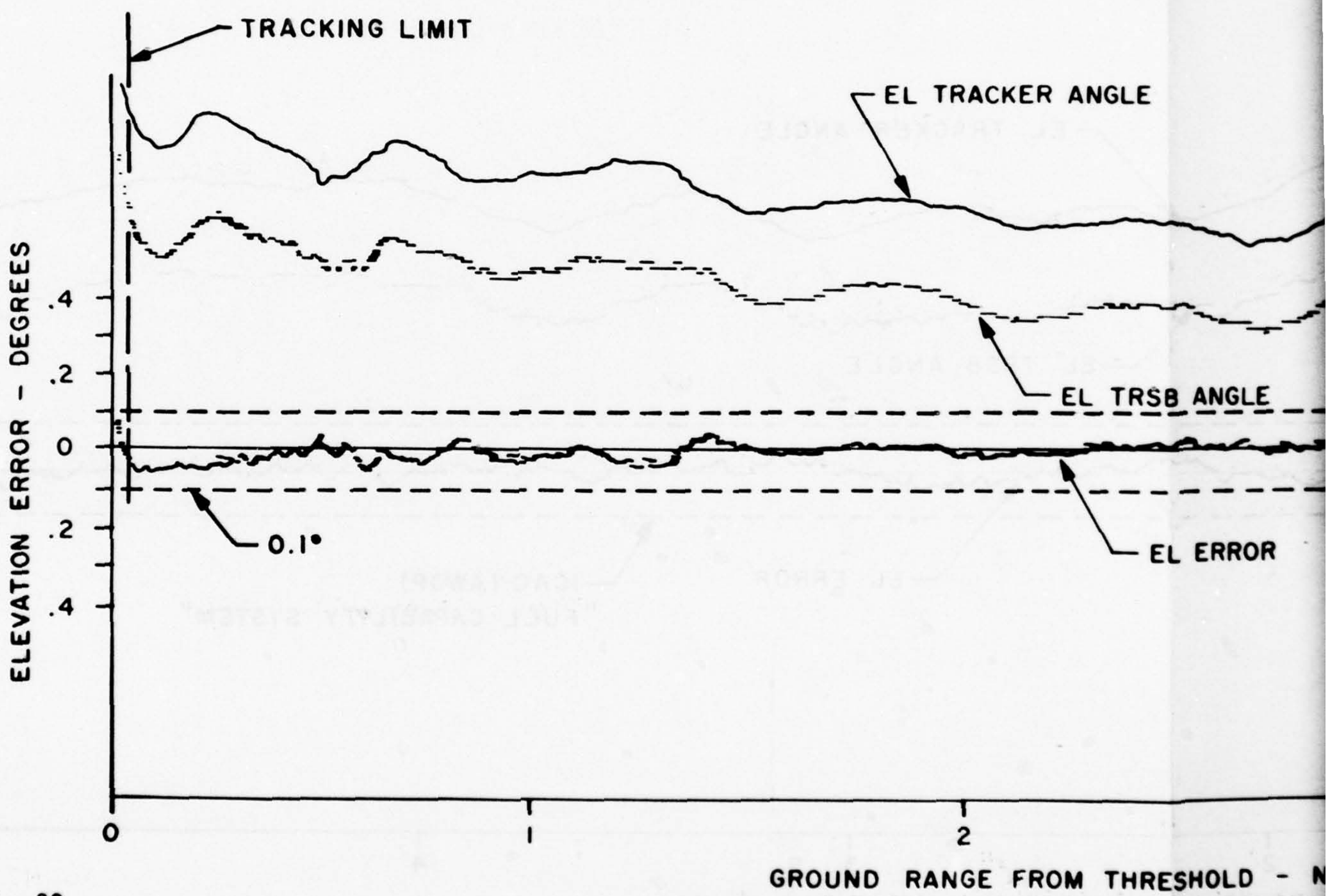
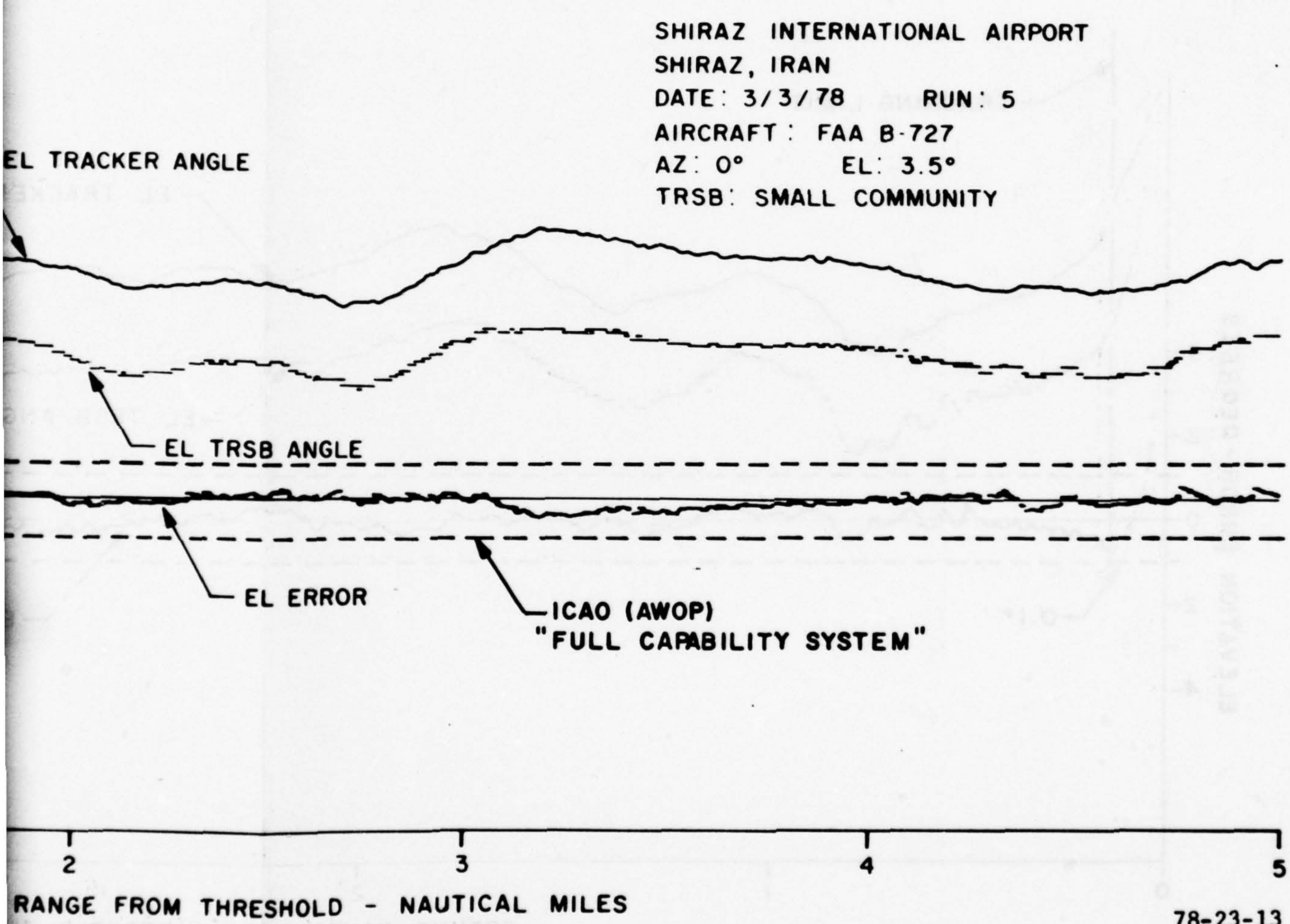


FIGURE 13. SAMPLE DATA PLOT FOR 3.5° DESCENT CENTERL



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PLOT FOR 3.5° DESCENT CENTERLINE APPROACH, ELEVATION TRACKED

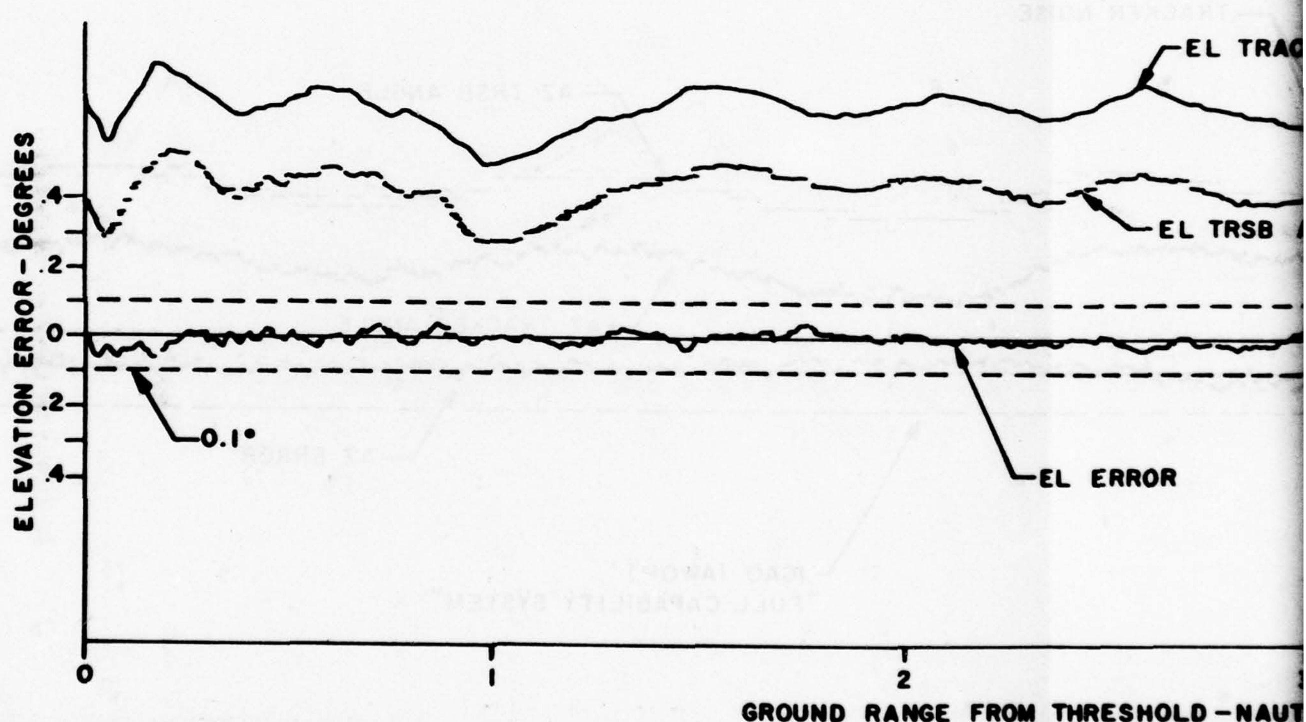
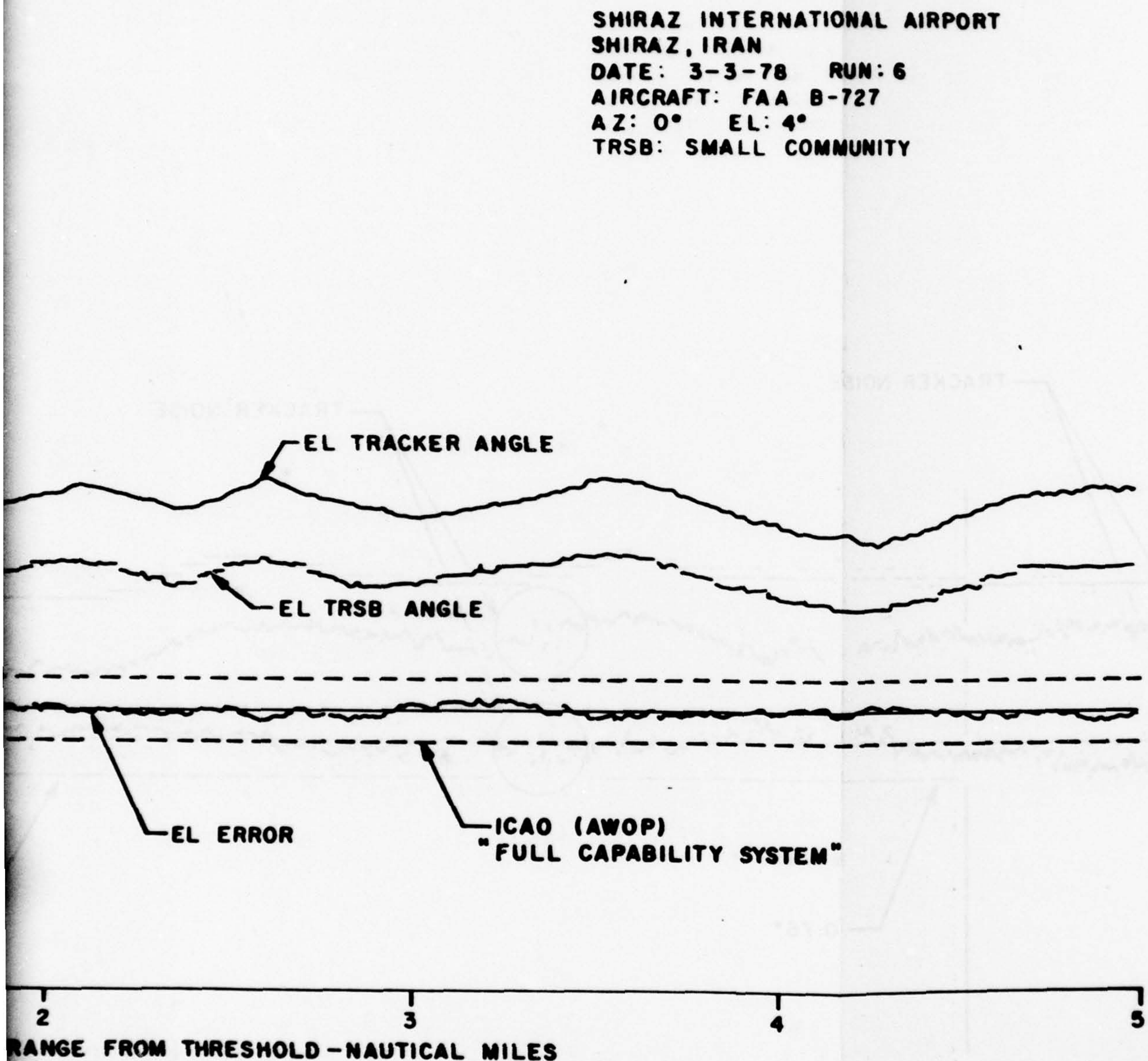


FIGURE 14. SAMPLE DATA PLOT FOR 4° DESCENT CENTERLINE A



OT FOR 4° DESCENT CENTERLINE APPROACH, ELEVATION TRACKED

78-23-14

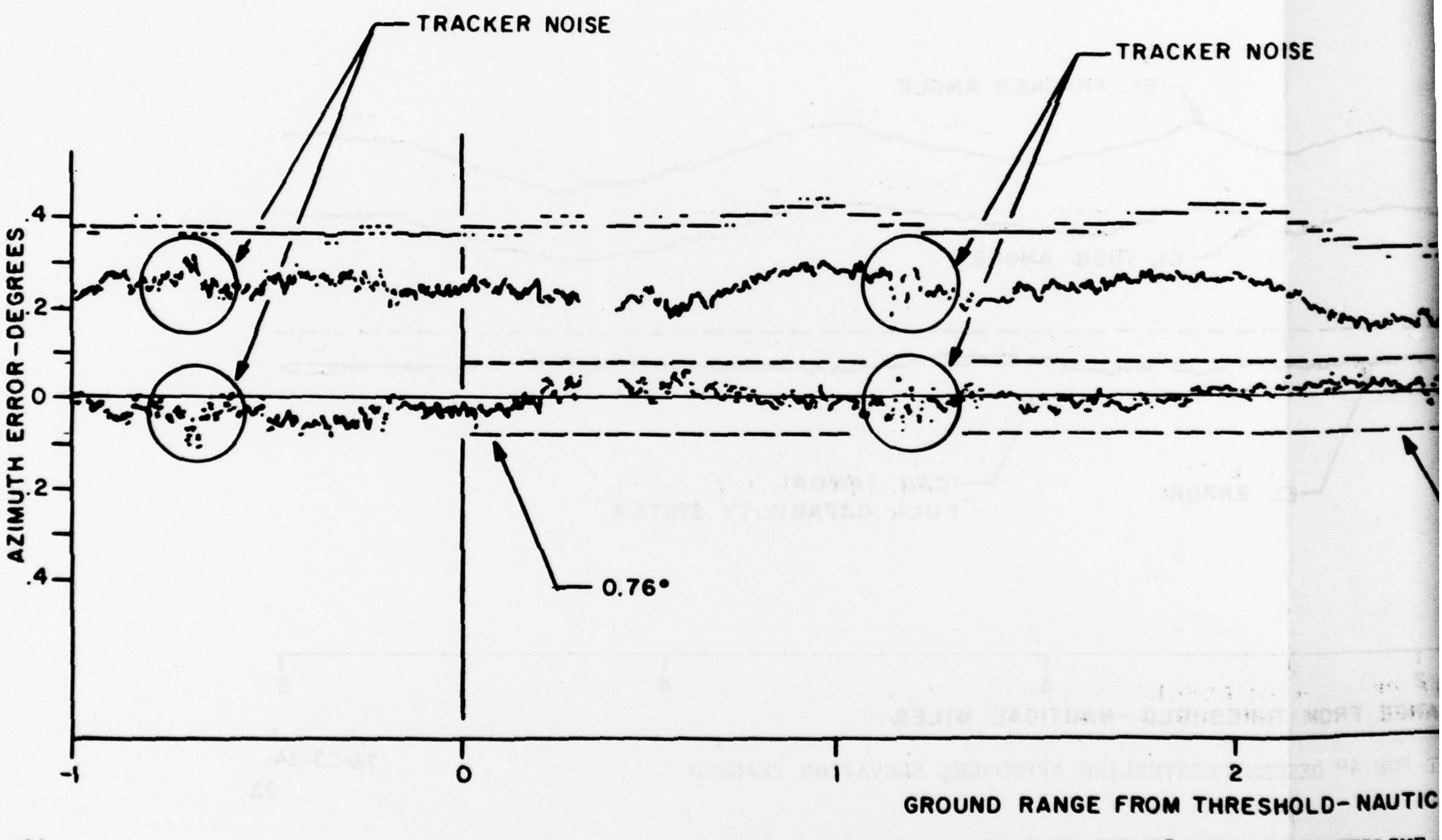
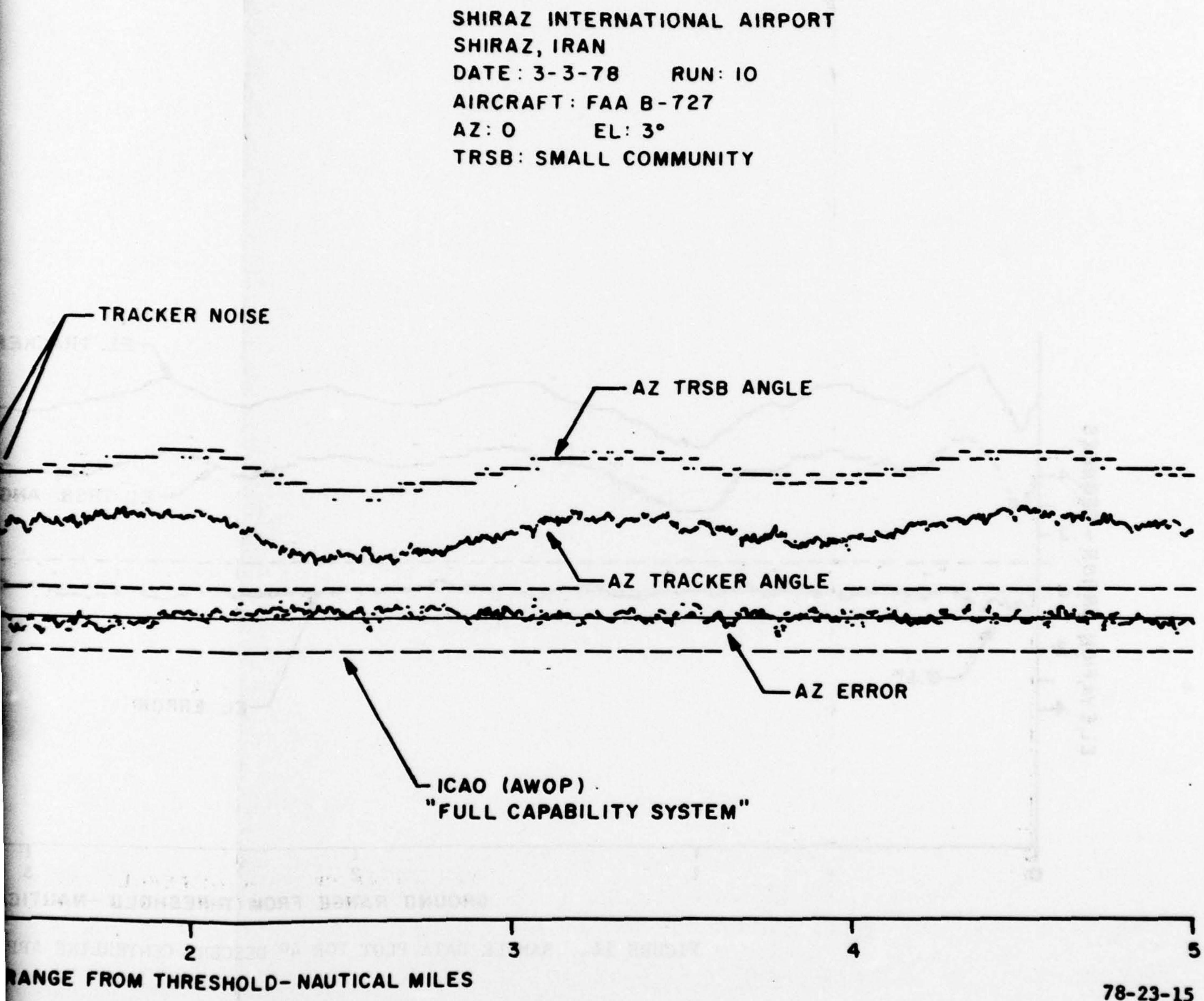


FIGURE 15. SAMPLE DATA PLOT FOR 3° DESCENT CENTERLINE



78-23-15

PLOT FOR 3° DESCENT CENTERLINE APPROACH, AZIMUTH TRACKED

2

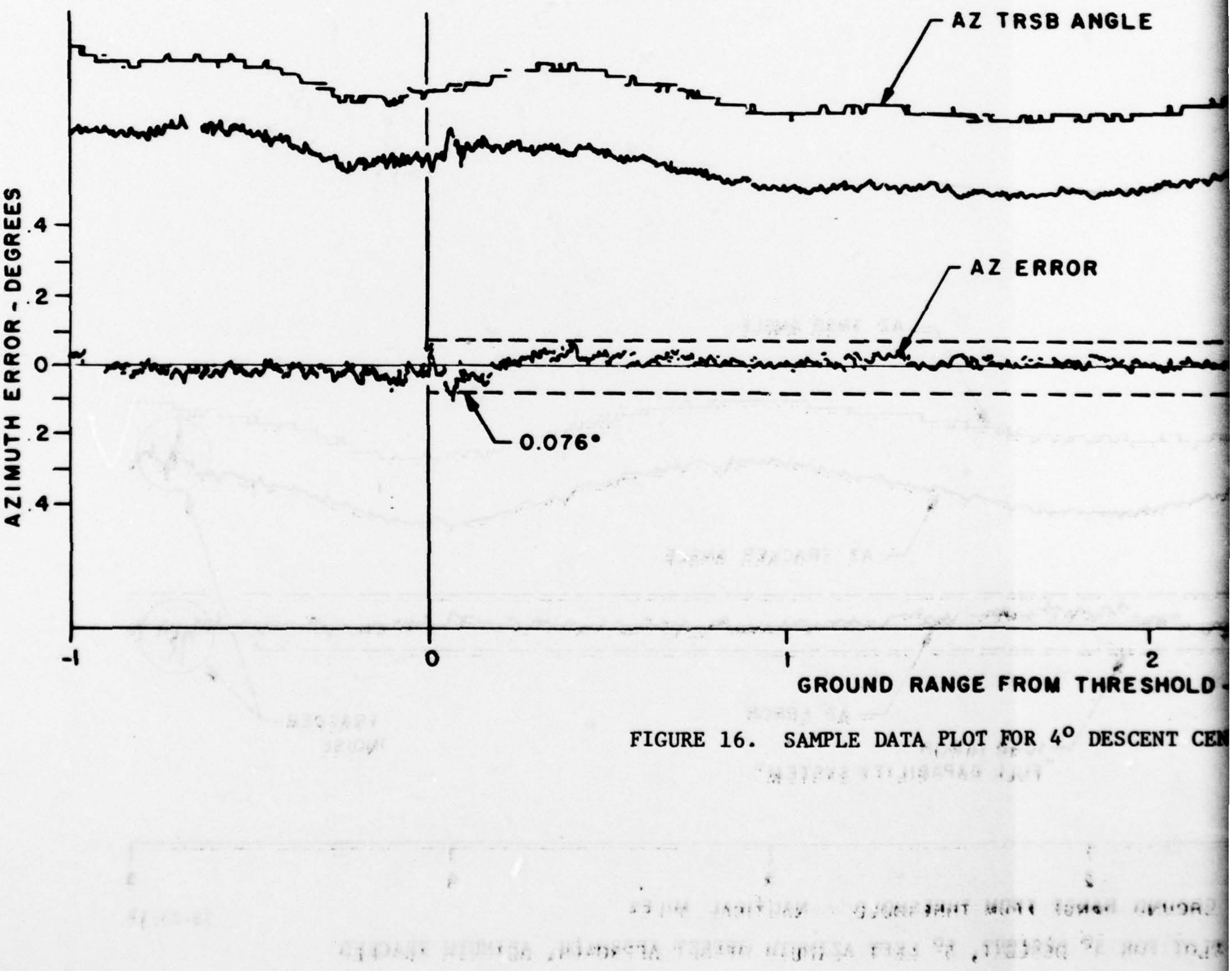
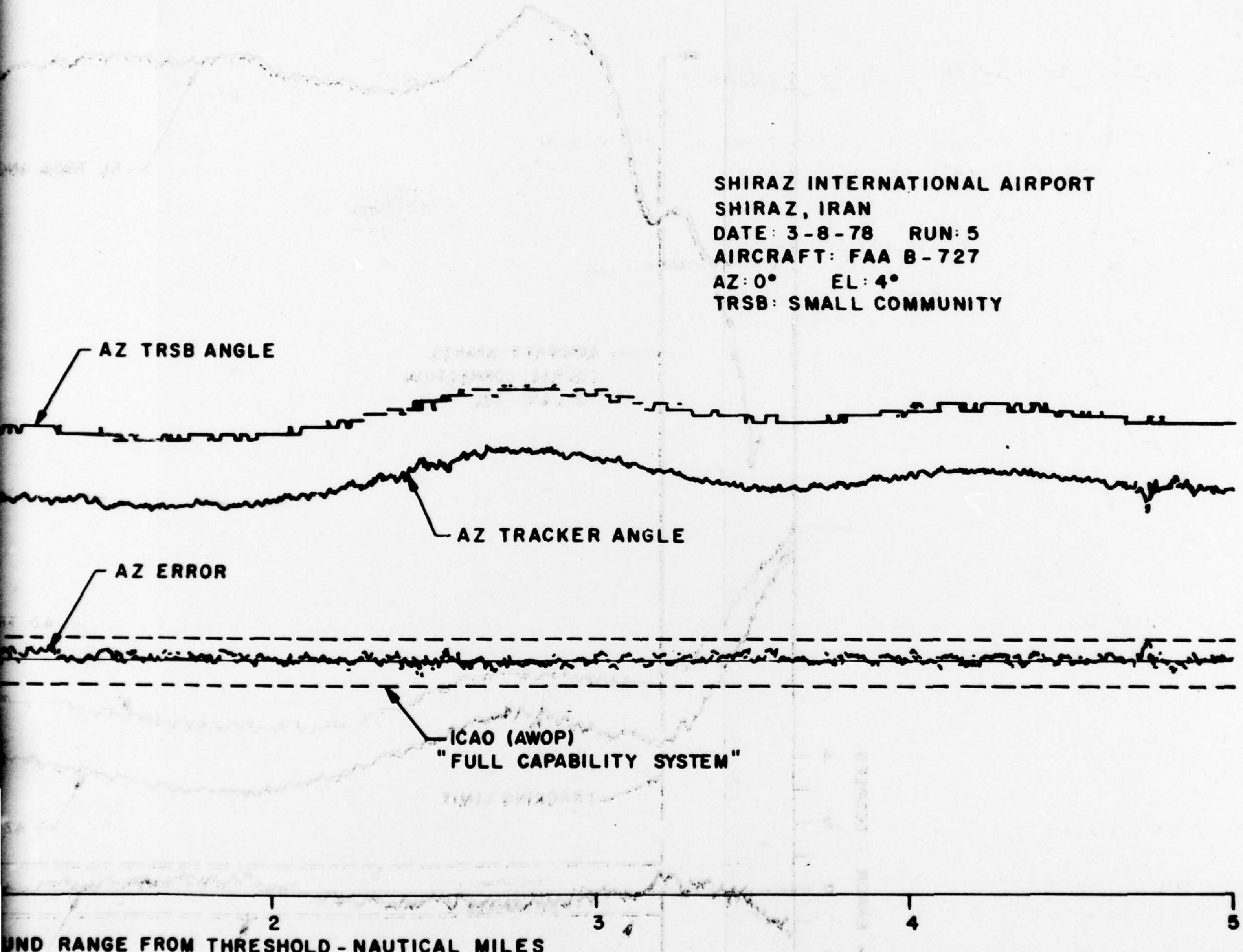


FIGURE 16. SAMPLE DATA PLOT FOR 4° DESCENT CEN



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E DATA PLOT FOR 4° DESCENT CENTERLINE APPROACH, AZIMUTH TRACKED

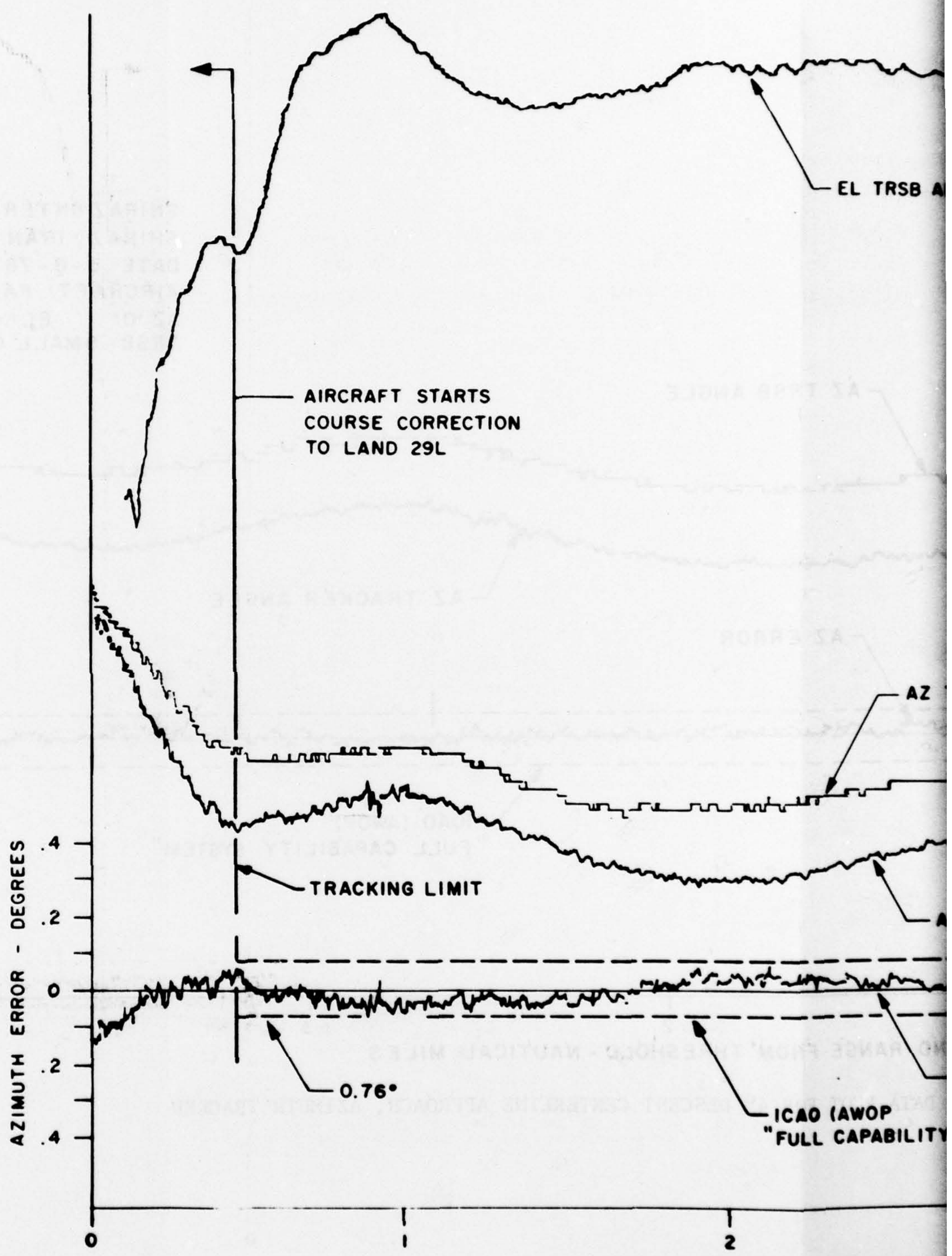
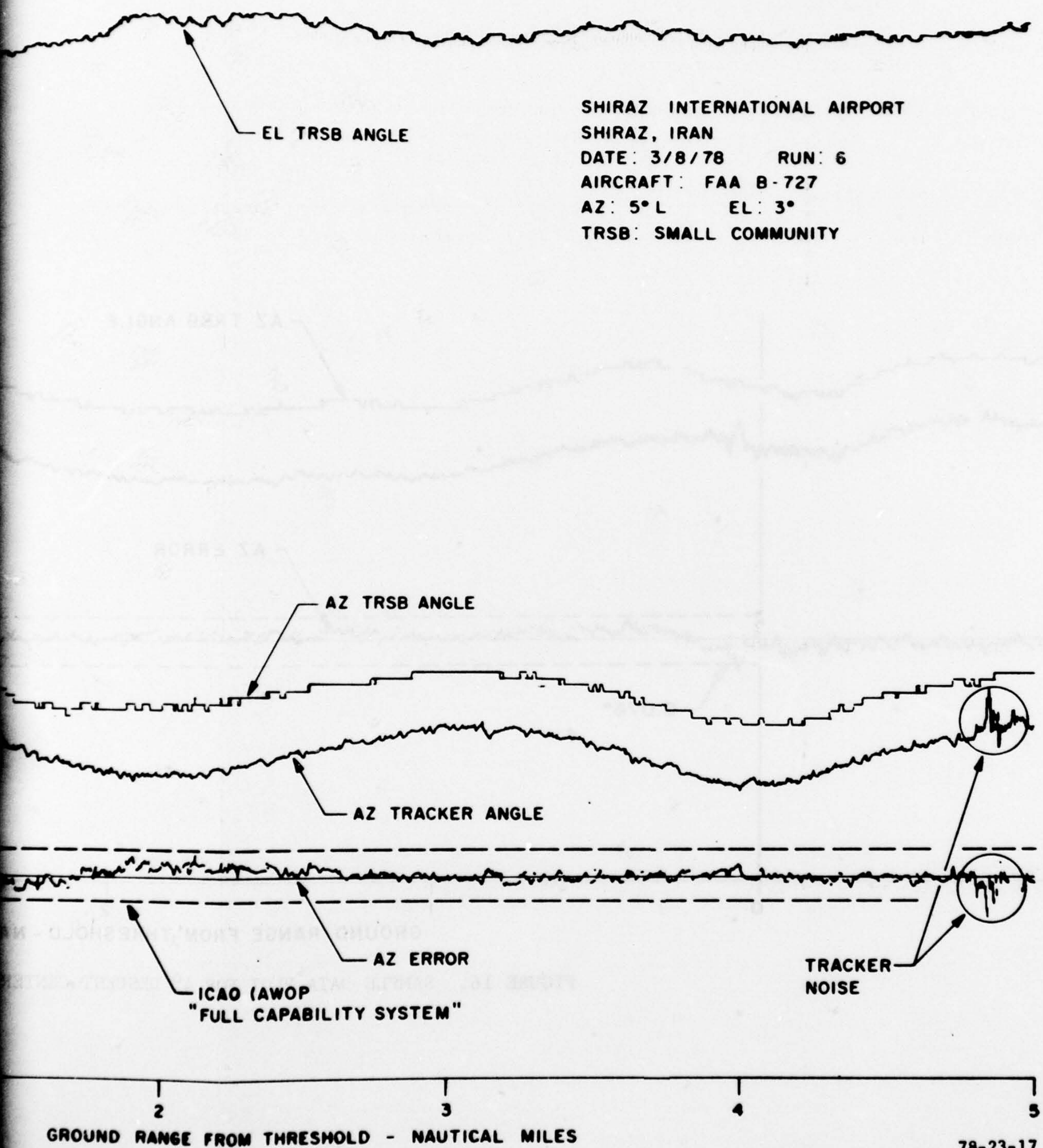


FIGURE 17. SAMPLE DATA PLOT FOR 3° DESCENT, 5° LEFT

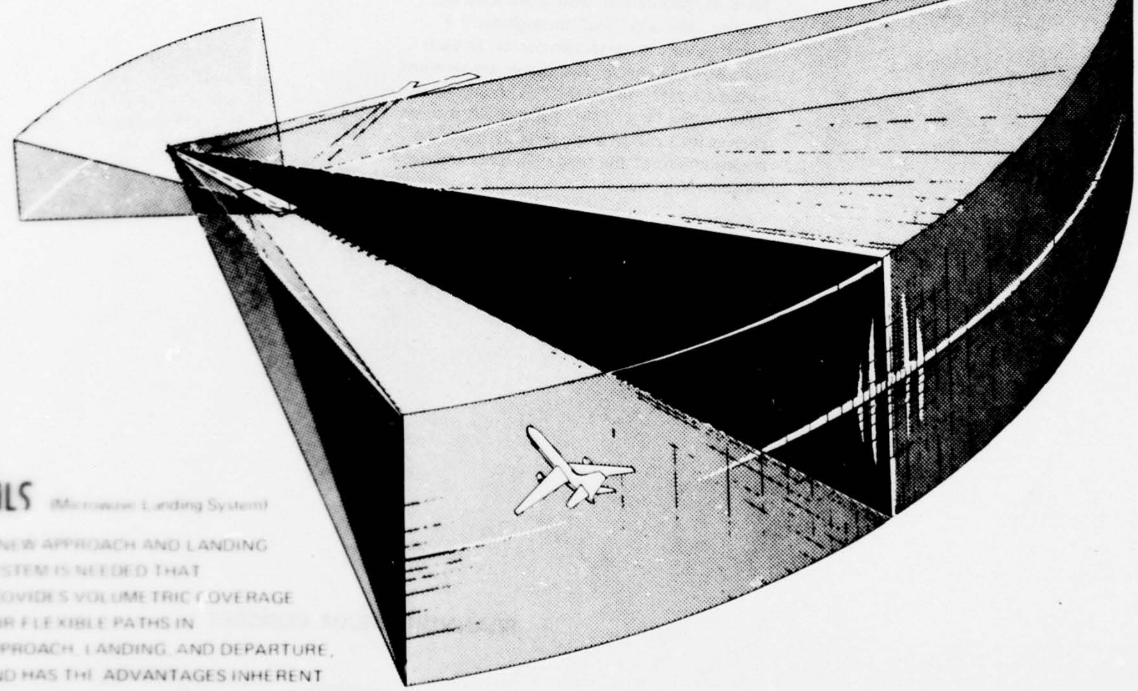


TA PLOT FOR 3° DESCENT, 5° LEFT AZIMUTH OFFSET APPROACH, AZIMUTH TRACKED

2

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

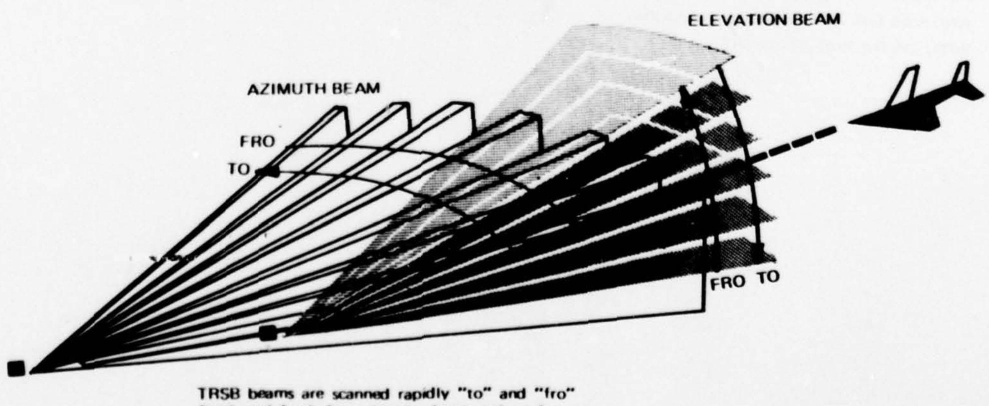
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data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



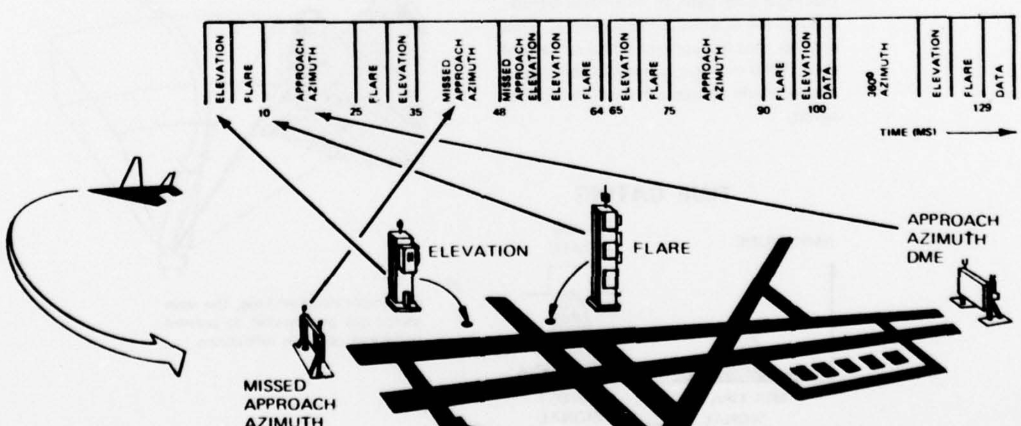
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

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.

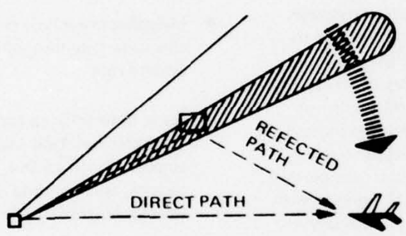


The TRSB signal offers maximum flexibility to meet unique user requirements

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.

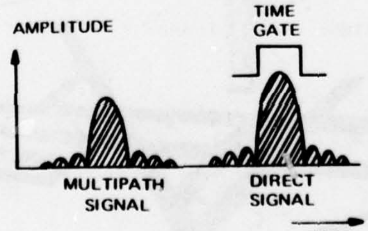
THERE ARE TWO TYPES OF MULTI-PATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival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



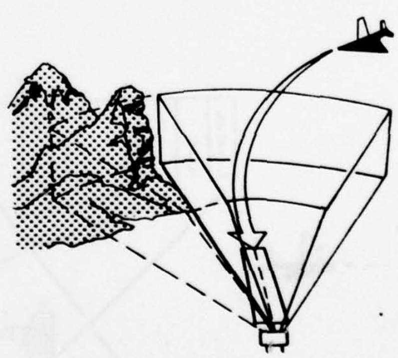
Time gating ensures that the correct signal is tracked, not the reflected one

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.

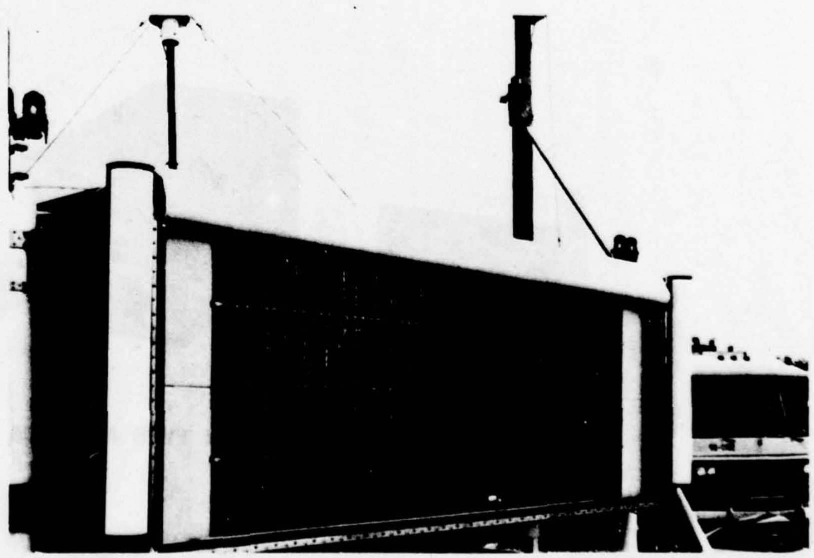
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide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



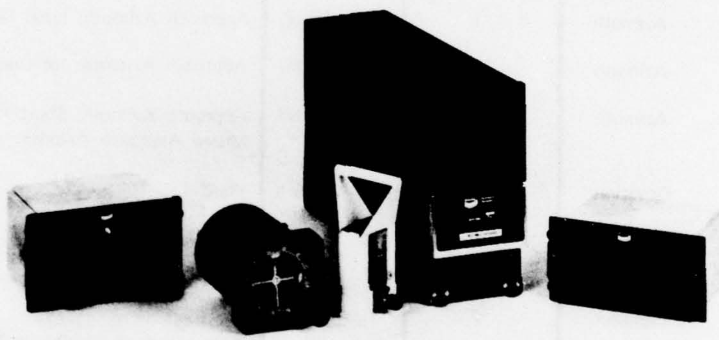
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

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.

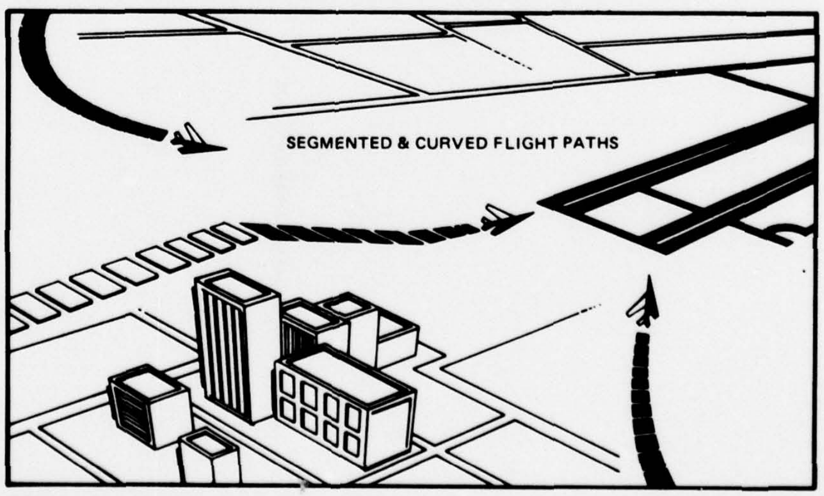
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

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