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An Operational Demonstration and Engineering Flight Test of the Microwave Landing System on Runway 22L at Chicago's Midway Airport

Clifford W. Mackin
Edmund Zyzys
Robert H. Pursel

October 1988

DOT/FAA/CT-TN88/42

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U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

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16. Abstract At the request of the Great Lakes Region, the Federal Aviation Administration (FAA) Technical Center conducted an operational demonstration of Microwave Landing System (MLS) on runway 22L at Chicago's Midway Airport. The MLS test bed installed at the FAA Technical Center was transported to, and temporarily installed at Chicago's Midway Airport. Three engineering flight tests were conducted on August 27, 28, and 29, 1988, to verify and characterize system operation. On August 30, three demonstration flights were conducted for the aviation industry, the media, and FAA personnel. Three profiles were designed for these flights to demonstrate the operational capabilities of MLS. The operational capability of MLS was successfully demonstrated and the MLS signal in space met Category II instrument landing system (ILS) tolerances.			
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The City of Chicago, IL

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EXECUTIVE SUMMARY

At the request of the Great Lakes Region, an operational demonstration of Microwave Landing System (MLS) was conducted by the Federal Aviation Administration (FAA) Technical Center on runway 22L at Chicago's Midway Airport. The MLS test bed installed at the FAA Technical Center was transported to, and temporarily installed at Chicago's Midway Airport. Three engineering flight tests were conducted on August 27, 28, and 29, 1988, to verify and characterize system operation. On August 30, three demonstration flights were conducted for FAA, the media, and aviation industry personnel. Three profiles were designed for these flights to demonstrate the operational capabilities of MLS. The operational capability of MLS was successfully demonstrated and the MLS signal in space met category II instrument landing system (ILS) tolerances.

INTRODUCTION

PURPOSE.

The purpose of this task was to demonstrate Microwave Landing System (MLS) operation on runway 22L at Chicago's Midway Airport and to collect flight test data for validation of the MLS math model.

BACKGROUND.

Midway Airport is surrounded by residential, commercial, and industrial buildings and has water retention basins (with varying water levels) alongside the runways making it a difficult site for instrument landing system (ILS) to achieve satisfactory performance. Midway Airlines, which conducts 40 percent of their operations at Midway Airport, expressed strong interest in an operational demonstration of MLS approaches to runway 22L, currently a nonprecision approach runway. Accordingly, the Great Lakes Region requested the Technical Center provide a temporary MLS installation at Midway Airport so as to demonstrate operational MLS Category I signal-in-space accuracies to runway 22L.

Since there are numerous tall structures (an air traffic control (ATC) tower, large hangars, etc.) and parked and docked aircraft at Midway Airport, it was determined that data collected during the operational demonstration would be useful for validation of the Lincoln Laboratory MLS math model. The model has been reconfigured since it was developed by the MIT Lincoln Laboratory during the early stages of the MLS program and requires some revalidation to ensure that it is performing satisfactorily.

DISCUSSION

MLS EQUIPMENT AND SITING.

The back azimuth and elevation stations from the MLS test bed system installed for runway 31 service at the Federal Aviation Administration (FAA) Technical Center were selected for the Midway Airport installation. The MLS test bed is a modified Bendix FAR-171 MLS (model B-21.5-40) which meets the FAA MLS accuracy tolerances: FAA-STD-022B and FAA-STD-022C. The back azimuth antenna (figure 1) has a 2° beamwidth with $\pm 40^\circ$ proportional azimuth guidance, and the elevation antenna (figure 2) has a 1.5° beamwidth with coverage from $+0.9^\circ$ to 15° elevation. At the FAA Technical Center, front azimuth guidance is provided by a 1° beamwidth antenna with $\pm 60^\circ$ proportional guidance. This station was not required for the Midway installation.

Under a maintenance support contract with Bendix, the 2° back azimuth station was electronically reconfigured to a front azimuth station. New programmable read only memories (PROMS) were installed for the basic data words for the Midway site configuration. The scan rate was changed from 6.5 to 13 hertz (HZ). In lieu of concrete foundations, new I-beam support frames (figure 3) were designed and fabricated for the azimuth and elevation stations for use at Midway.

After the front azimuth and data word changes were made, the MLS was checked out at the Technical Center employing the C-band air sync provided with the system. Air sync was required for Midway because land lines are not installed between

the azimuth and elevation sites on runway 22L. Also, the new support frames were test fitted at the Technical Center to ensure proper shelter and antenna alignment (figures 4 and 5). Each antenna was removed from its pedestal and secured and packed for shipment (figures 6 - 10). An instrumented test van with an MLS receiving antenna mounted on a telescoping mast (figure 11) was driven from the Technical Center to Midway for system alignment prior to flight testing.

On August 23 the equipment was loaded on a truck for shipment to Midway (figure 12). It was delivered at 0800 on August 25, unloaded, leveled, and mechanically aligned at each site by 1200 on the same day. Survey stakes provided by region personnel were used for runway alignment. Power from portable diesel generators (one for each site), arranged for by the Midway Airway Facility Sector (AFS), was connected to each station on the same day. A layout of the siting geometry is shown in figure 13. Figures 14 and 15 show the MLS azimuth and elevation stations as installed at Midway Airport. The commissioned field Distance Measuring Equipment (DME) at Midway was utilized for ranging because no Precision Distance Measuring Equipment (DME/P) was available for these tests and demonstrations.

Both stations were powered up on the following day. Alignment of the antennas was accomplished using the instrumented test van. The MLS receiving antenna was placed on the runway centerline at the displaced threshold at a height of 45 feet (ft). The MLS receiver angle reading was used to set the azimuth boresight.

ENGINEERING FLIGHT TESTS.

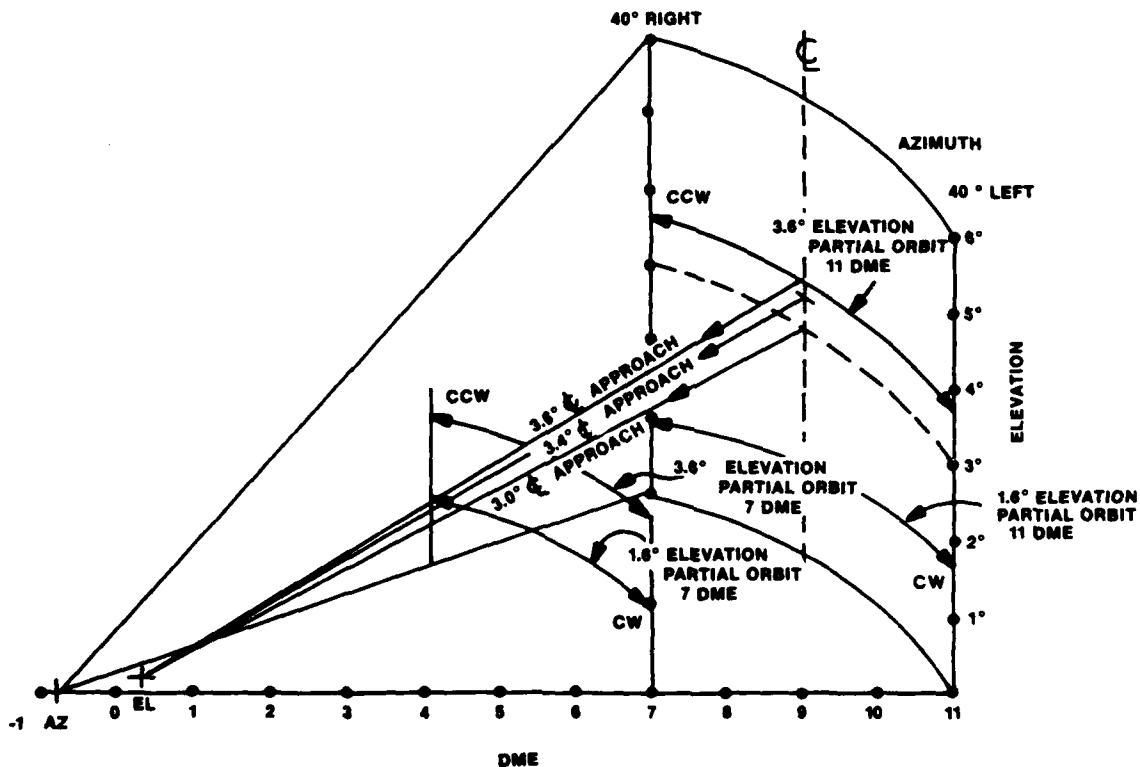
Before the instrumented MLS aircraft (N-91), a Convair-580 (figure 16), departed for Midway, a new data collection system was designed, fabricated, installed, and checked out by Technical Center personnel. This was required because the frequency modulation (FM) radio telemetric theodolite (RTT) used for aircraft space position data had not been previously utilized by the Technical Center for fixed wing MLS data.

Engineering test flights were conducted on August 27, 28, and 29. A listing and diagram of the profiles flown appears in table 1. The engineering test flights included a series of untracked partial orbits through the MLS coverage volume and tracked approaches from a range of approximately 10 nautical miles (nmi) from threshold. The purpose of the test flights was to provide data to validate the MLS math model and to insure that the proposed demonstration flight profiles were operationally feasible.

The partial orbits were flown at ranges from the Midway field DME of 11 nmi at altitudes of 4,900 ft mean sea level (m.s.l) and 2,400 ft m.s.l and 7 nmi at altitudes of 3,000 ft m.s.l. and 1,700 ft m.s.l. These altitudes and ranges were calculated to allow two orbits at each range to be flown at MLS elevation angles of 3.6° and 1.6° . The 3.6° elevation angle orbit permitted, at both ranges, direct line-of-sight from the aircraft to the MLS ground stations at all times during the run and provided a clean MLS signal-in-space for comparison purposes. The 1.6° elevation angle orbit placed the aircraft physically below the tops of several high obstacles to the north of Midway Airport (i.e. large smokestacks, the Sears and John Hancock buildings, as well as several aircraft hangars on the airport). The data from these runs provided useful input to the math model validation with respect to the interaction of the MLS signals in space with

TABLE 1. MLS ENGINEERING TEST FLIGHT PROFILES

<u>Run Type</u>	<u>Description</u>	
Partial Orbit	ccw, 40° left	to 40° right , 11 DME, 4,900 ft m.s.l (3.6° Glideslope)
Partial Orbit	cw 40° right	to 40° left , 11 DME, 4,900 ft m.s.l (3.6° Glideslope)
Partial Orbit	ccw 40° left	to 40° right , 11 DME, 2,400 ft m.s.l (1.6° Glideslope)
Partial Orbit	cw 40° right	to 40° left , 11 DME, 2,400 ft m.s.l (1.6° Glideslope)
Partial Orbit	ccw 40° left	to 40° right , 7 DME, 3,000 ft m.s.l (3.6° Glideslope)
Partial Orbit	cw 40° right	to 40° left , 7 DME, 3,000 ft m.s.l (3.6° Glideslope)
Partial Orbit	ccw 40° left	to 40° right , 7 DME, 1,700 ft m.s.l (1.6° Glideslope)
Partial Orbit	cw 40° right	to 40° left , 7 DME, 1,700 ft m.s.l (1.6° Glideslope)
Approach	3.6° Elevation angle,	10 DME, 3,100 ft m.s.l intercept
Approach	3.4° Elevation angle,	10 DME, 3,100 ft m.s.l intercept
Approach	3.0° Elevation angle,	10 DME, 3,100 ft m.s.l intercept



obstructions comprised of complex vertical surfaces. Examples of orbital data for the 11 nmi 4,900 ft m.s.l. and 2,400 ft m.s.l. partial orbits are shown in figures 17 and 18, respectively. Figure 18 shows the effects of shadowing and diffraction of the MLS elevation signal by the high obstructions mentioned above. An examination of signal strength associated with the run reveals a large drop in signal strength coincident with the perturbation in figure 18. The location of the perturbation relative to azimuth angle coincides exactly with the location of the old aircraft hangar adjacent to the approach end of runway 22L.

The approaches were flown at elevation angles of 3.0° , 3.4° , and 3.6° to investigate the MLS signal-in-space of the coverage volume that was utilized for the demonstration profile. Examples of approach data for each of the elevation angles are shown in figures 19 through 24. The path following error (PFE) and control motion noise (CMN) plots are obtained by first taking the differential between the MLS signal as recorded in the aircraft, and the output of the RTT receiver also recorded in the aircraft. The resultant differential is the actual position in space of the MLS signal. The resultant differential signal is then processed through standard filter algorithms to obtain the PFE and CMN values. Tolerance limit lines were also put on the PFE and CMN plots. Both the filter algorithm and the tolerance limits are contained in FAA-STD-022B. As can be seen from inspection of the approach data, the MLS signal-in-space was free from radio frequency (RF) interference at all times as well as free from the effects of any multipath which may have been caused by the buildings and structures surrounding the airport.

DEMONSTRATION FLIGHTS.

On Tuesday, August 30, three MLS demonstration flights were conducted. Approximately 25 participants from FAA Headquarters, Great Lakes Region, aviation industry, media personnel, and airlines using Midway Airport flew on the flights. A list of the personnel and their affiliations are shown in table 2.

Three demonstration profiles were designed by Mr. John Ryan, ACN-331, MLS project test pilot, and Mr. Cliff Mackin, ACD-330, MLS Technical Program Manager. These profiles were designed to show the operational flexibility of MLS with just the basic airborne receiver installed in the aircraft. Profile 1 (figure 25) is a basic ILS look-alike runway centerline, 3.0° elevation angle approach. Profile 2 (figure 26) starts out as a 3.6° elevation angle approach. At the 8.0 DME point, the 3.6° elevation setting on the MLS receiver control head is manually changed to 3.0° , a gentle pushover of the aircraft is initiated, and the 3.0° elevation beam is reacquired well prior to the 5.0 DME point. For profile 3 (figure 27) the initial azimuth angle set in on the MLS receiver control head is 238° . This allows the initial inbound segment to be flown on a 15° left radial with respect to the extended runway centerline (223°). The aircraft intercepts the 15° left azimuth radial set on the MLS receiver control head from the 13.0 DME arc. At the 10.0 DME point, the azimuth angle set on the receiver control head is manually changed to 223° (extended runway centerline or 0° azimuth radial). The aircraft turns right to a heading of 265° , and reacquires the 223° radial prior to the 7 DME point. Continuous elevation guidance of 3.0° is provided throughout this profile. On demonstration flight 3, the changeover point for switching from the 15° left radial to the centerline radial was changed from 10 DME to 8.8 DME, with the intercept of the 0° centerline radial occurring prior to 5 DME.

TABLE 2. MLS DEMONSTRATION FLIGHTS MIDWAY AIRPORT
AUGUST 30, 1988

FLIGHT 1

Jim Tilmon	Channel 5 Aviation Reporter
Cameraman	Channel 5
Dick Arnold	FAA MLS Program Manager
Dick White	Air Transport Assn.
Paul Lenard	Air Transport Assn.
Dave Temples	American Airlines
Carl Price	American Airlines
Larry Wilson	American Airlines
Cliff Mackin	FAA Tech Center, ACD-330
John Morrow	FAA Tech Center, ACD-330

FLIGHT 2

Dean Del Bene	Aircraft Ins.
Judy Loren	Chicago Skyline
Ron Bolt	Beatrice Flt. Dept.
Dennis Brown	Ameritech Flt. Dept.
Terry Hyatt	Amoco Flt. Dept.
Al Lane	Amoco Flt. Dept.
Pete Davis	United Airlines
Andy Stasuik	FAA HQ, ASA-130
Emmett Stovall	N.A.C.
Bob Pursel	FAA Tech Center, ACD-330
John Morrow	FAA Tech Center, ACD-330

FLIGHT 3

Ed Mulligan	Midway Airlines
Merle Hodel	Midway Airlines
Dave Vance	Midway Airlines
Ross Hutchenson	Midway Airlines
Dick Corn	Great Lakes Reg. Office
Andy Stasiuk	FAA HQ, ASA-130
Dick Arnold	FAA MLS Program Manager
Rick Murphy	Great Lakes Regional Office
Lou Yates	Great Lakes Regional Office
Cliff Mackin	FAA Tech Center, ACD-330
Bob Pursel	FAA Tech Center, ACD-330
John Morrow	FAA Tech Center, ACD-330

All of these profiles were easily flown. In fact, some of the profiles were flown down to a decision height of 100 feet above ground level by some of the observers on the demonstration flights who were also qualified pilots.

CONCLUSIONS

1. The temporary installation of Microwave Landing System (MLS) on runway 22L at Chicago Midway Airport and the resultant flights satisfactorily demonstrated the operational capability of MLS at that site.
2. Performance of the MLS met the requirements for instrument landing system (ILS) Category II signal-in-space.
3. No radio frequency (RF) interference was observed on the MLS signal in the vicinity of the high power frequency modulation (FM) and television (TV) signals from antennas located on tall buildings in downtown Chicago.

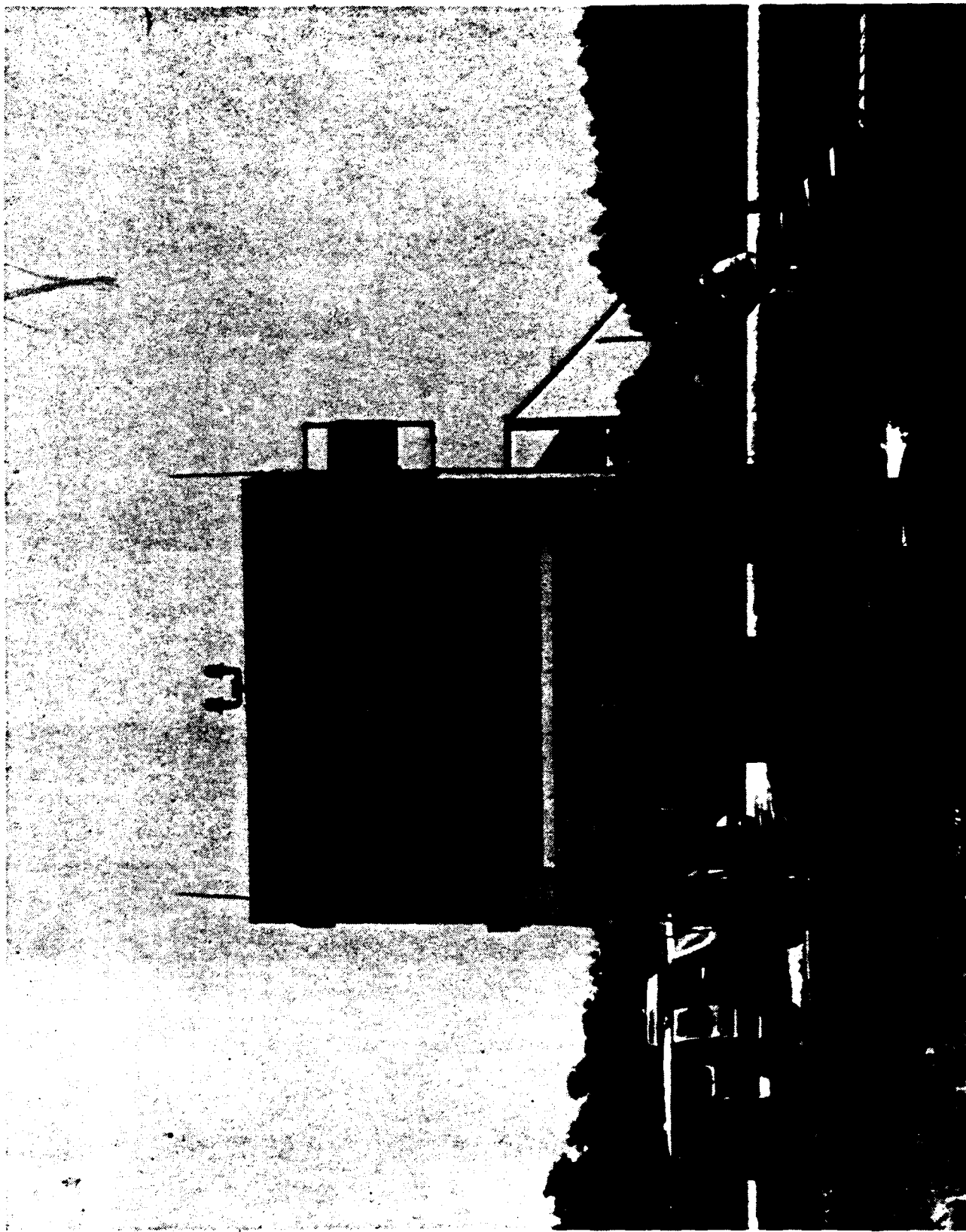


FIGURE 1. BACK AZIMUTH INSTALLATION AT THE FAA TECHNICAL CENTER

88-2317

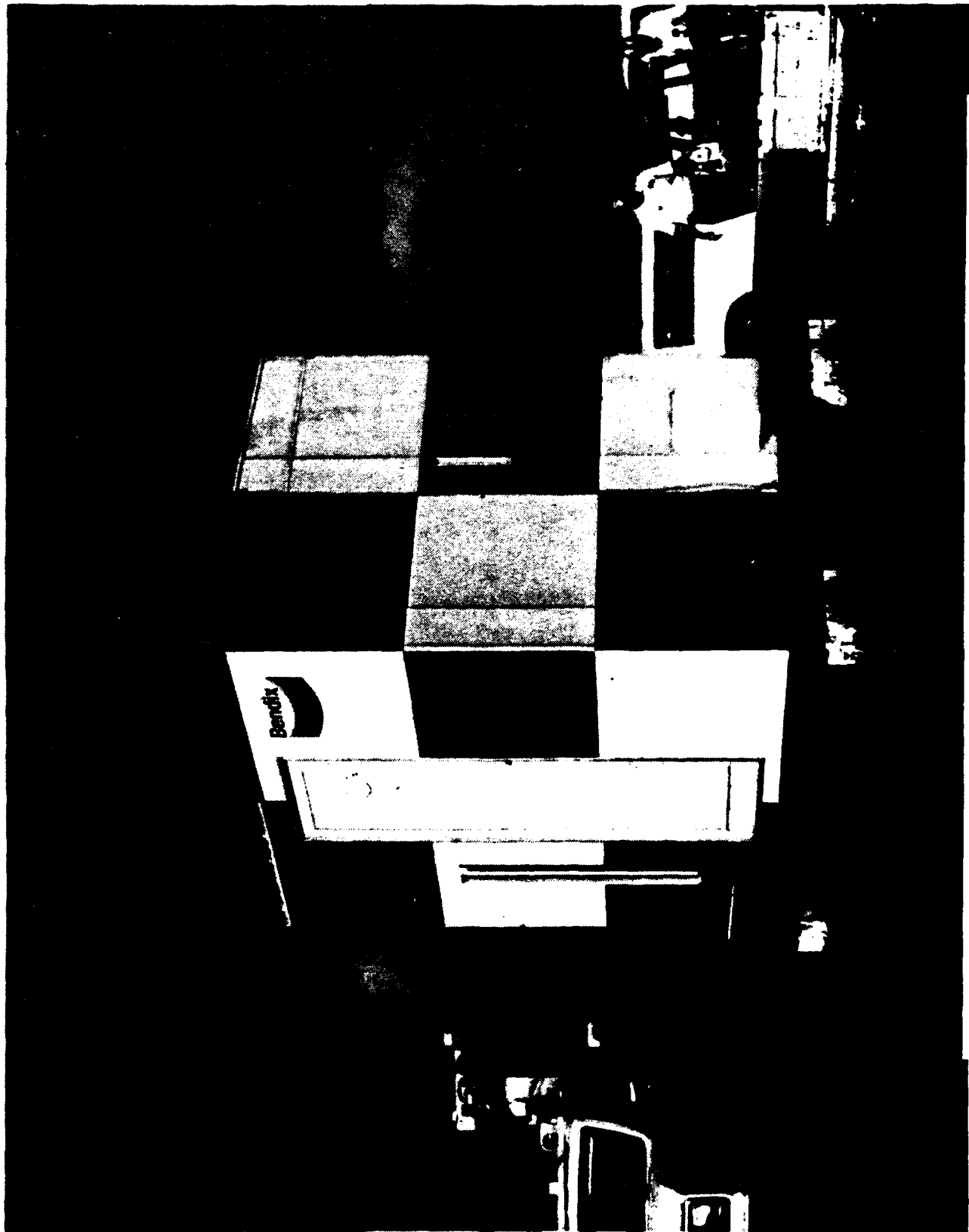


FIGURE 2. MLS ELEVATION INSTALLATION AT THE FAA TECHNICAL CENTER

88-2352

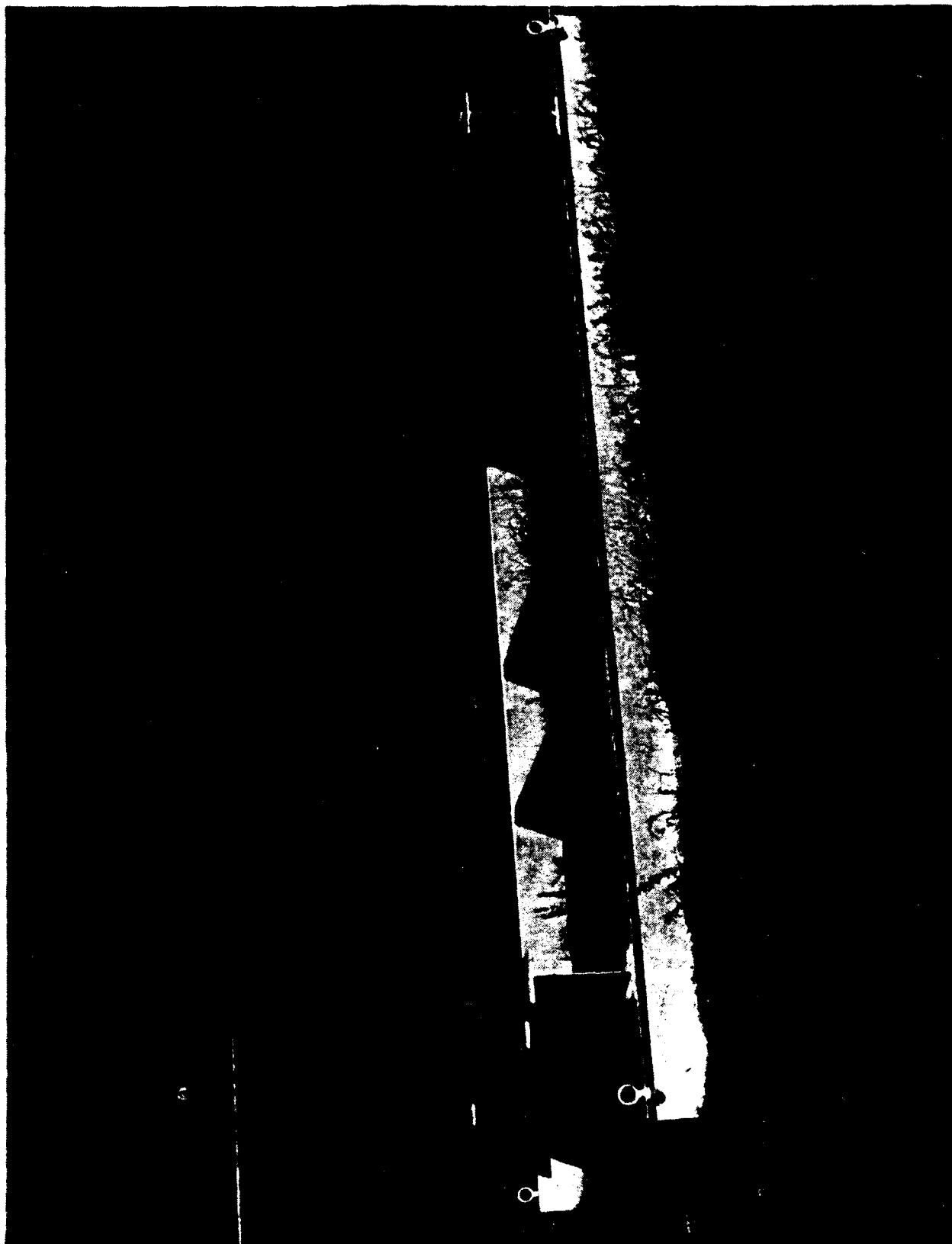


FIGURE 3. MLS SHELTER SUPPORT FRAME

88-2388

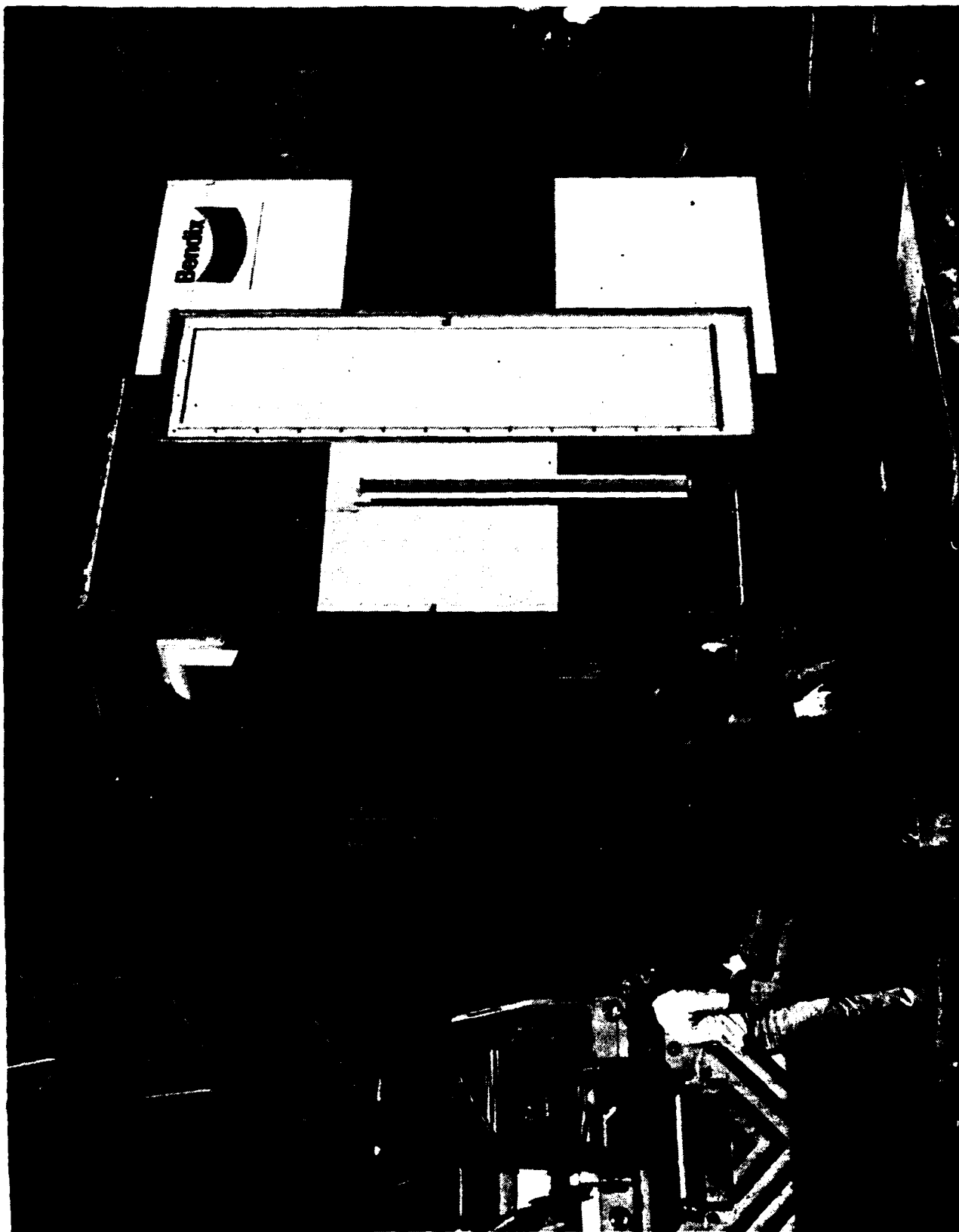
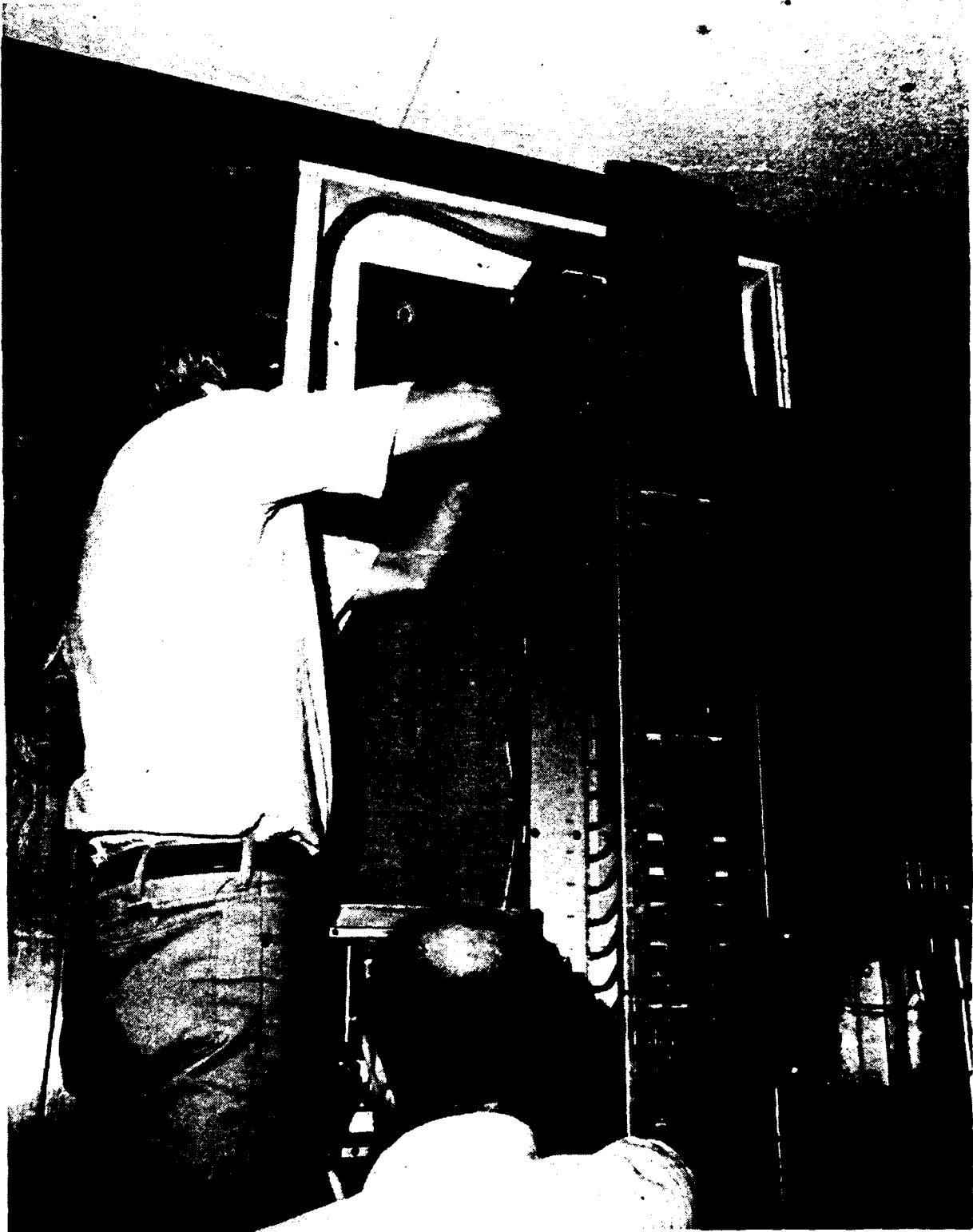


FIGURE 4. MLS SHELTER SUPPORT FRAME TEST FIT

88-2-379



88-2380 FIGURE 5. MLS SHELTER SUPPORT FRAME TEST FIT (DETAILED VIEW)



88-2326

FIGURE 6. ELEVATION ANTENNA REMOVAL (INTERIOR VIEW)



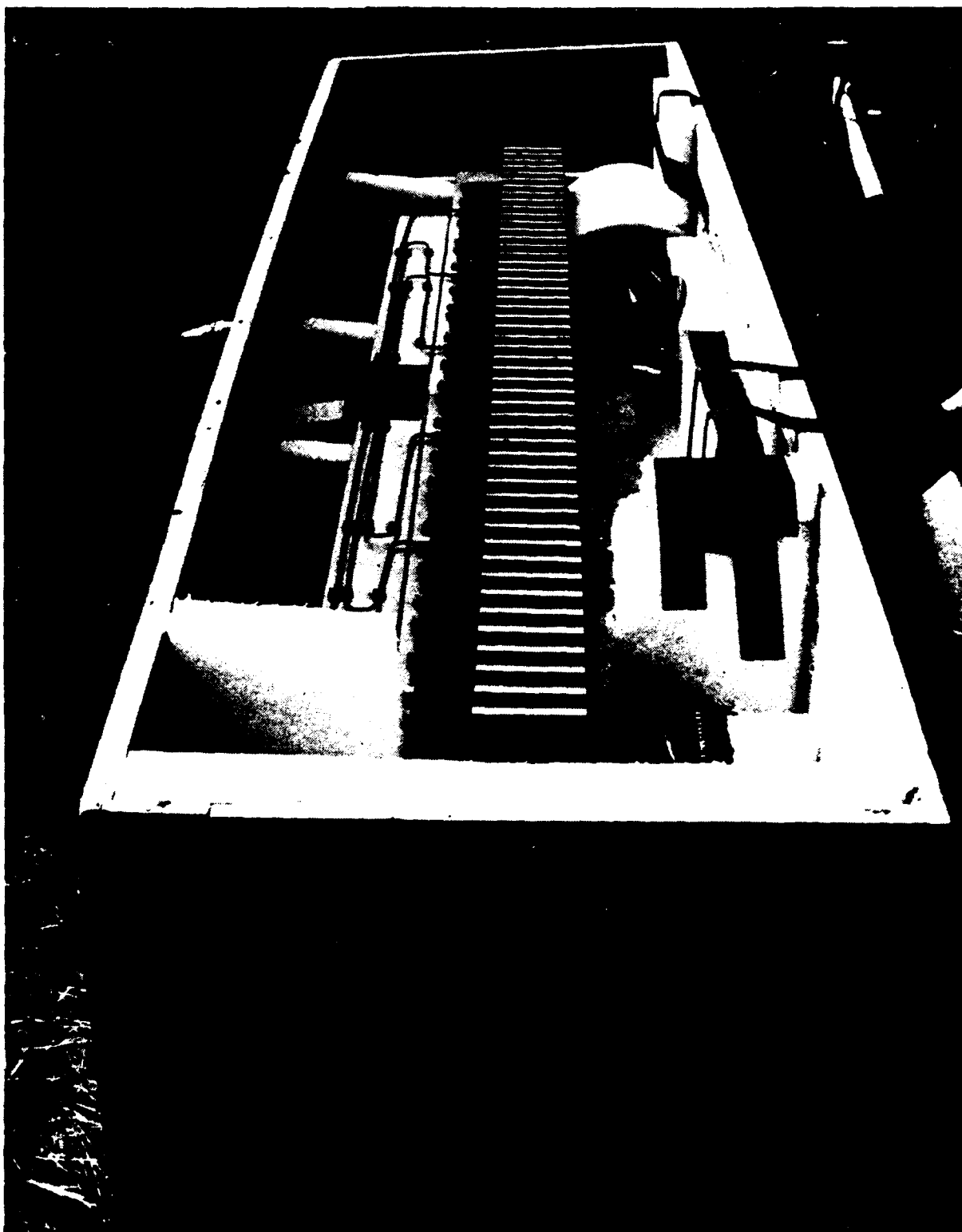
FIGURE 7. ELEVATION ANTENNA REMOVAL

88-2330



FIGURE 8. ELEVATION ANTENNA PACKING FOR SHIPMENT

88-2332



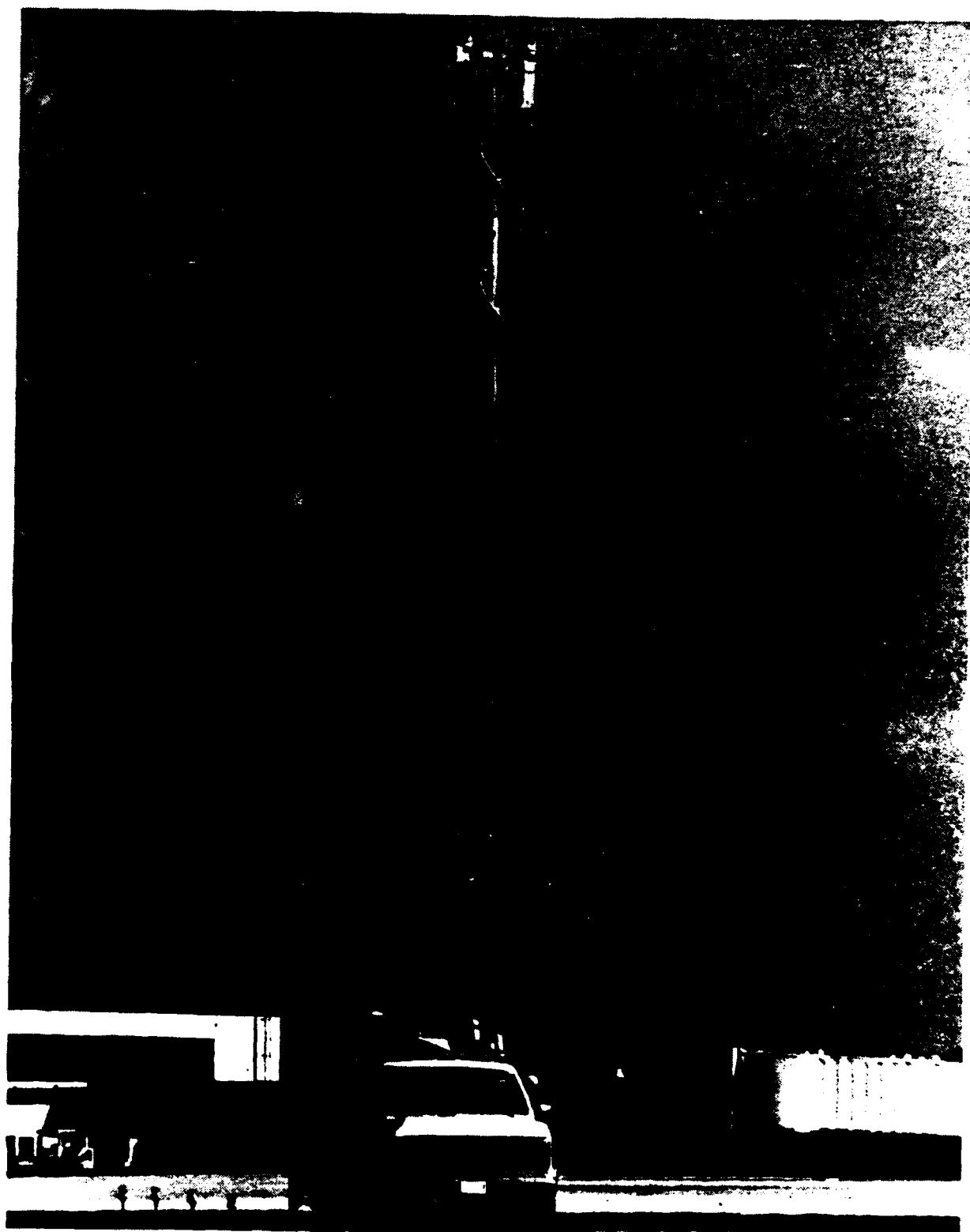
88-2358

FIGURE 9. ELEVATION ANTENNA IN SHIPPING CRATE



FIGURE 10. AZIMUTH ANTENNA REMOVAL

88-2322



88-2607

FIGURE 11. INSTRUMENTED TEST VAN DURING MLS ANTENNA BORESIGHT ALIGNMENT

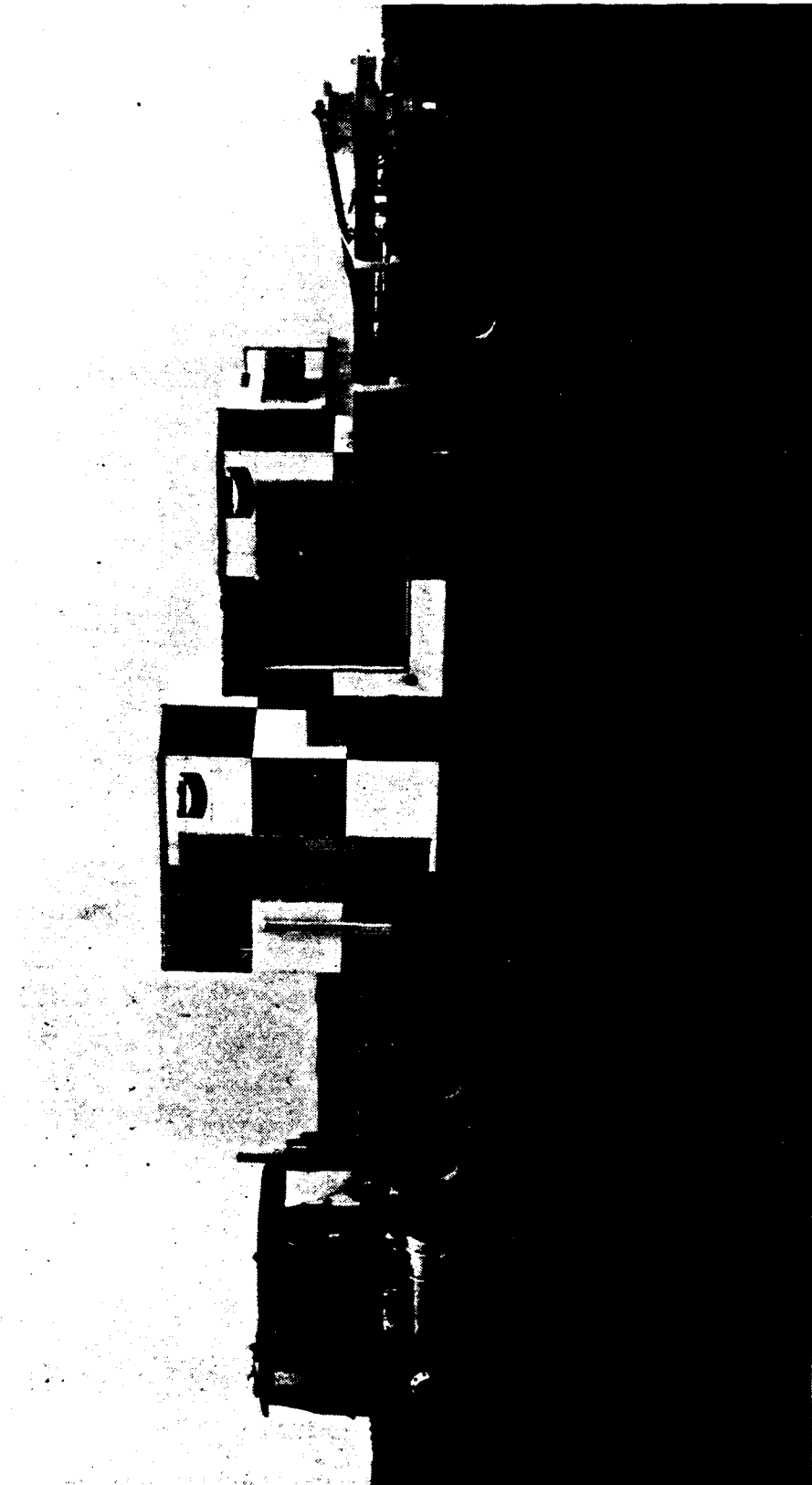
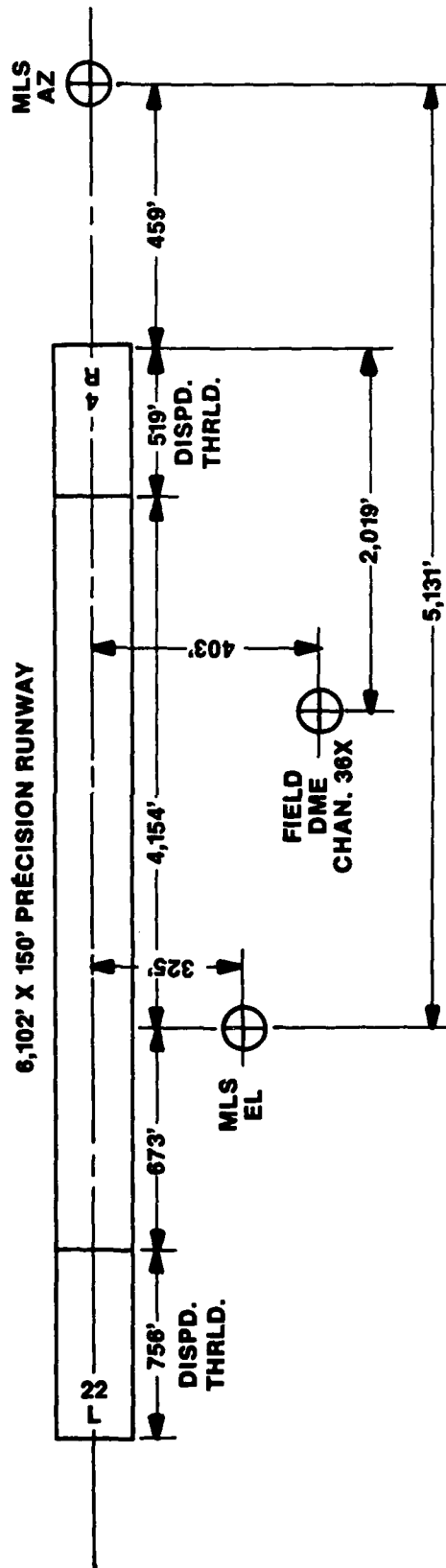


FIGURE 12. MLS EQUIPMENT LOADED ON TRUCK

88-2648

MLS CHANNEL 600 (5061.0 MHz)



DWG. NOT TO SCALE

FIGURE 13. MLS SITING AT MIDWAY AIRPORT



FIGURE 14. AZIMUTH STATION AT MIDWAY AIRPORT

88-2629



FIGURE 15. ELEVATION STATION AT MIDWAY AIRPORT (REAR VIEW)

88-2601

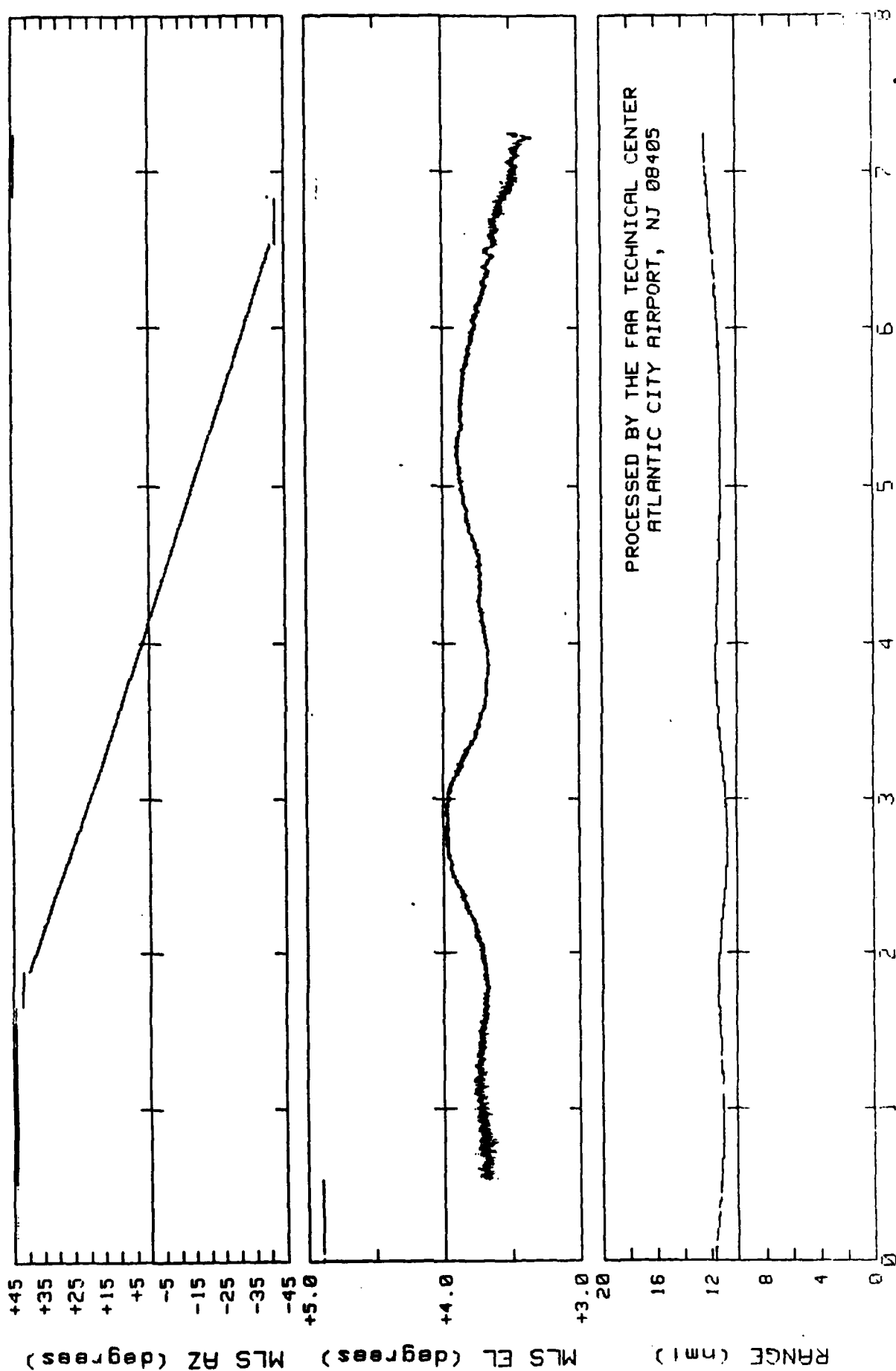


FIGURE 16. INSTRUMENTED MLS AIRCRAFT (N-91)

88-2621

FRA MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL

DATE 8-27-88 TIME 5:56:56 11 nmi DME PARTIAL ORBIT

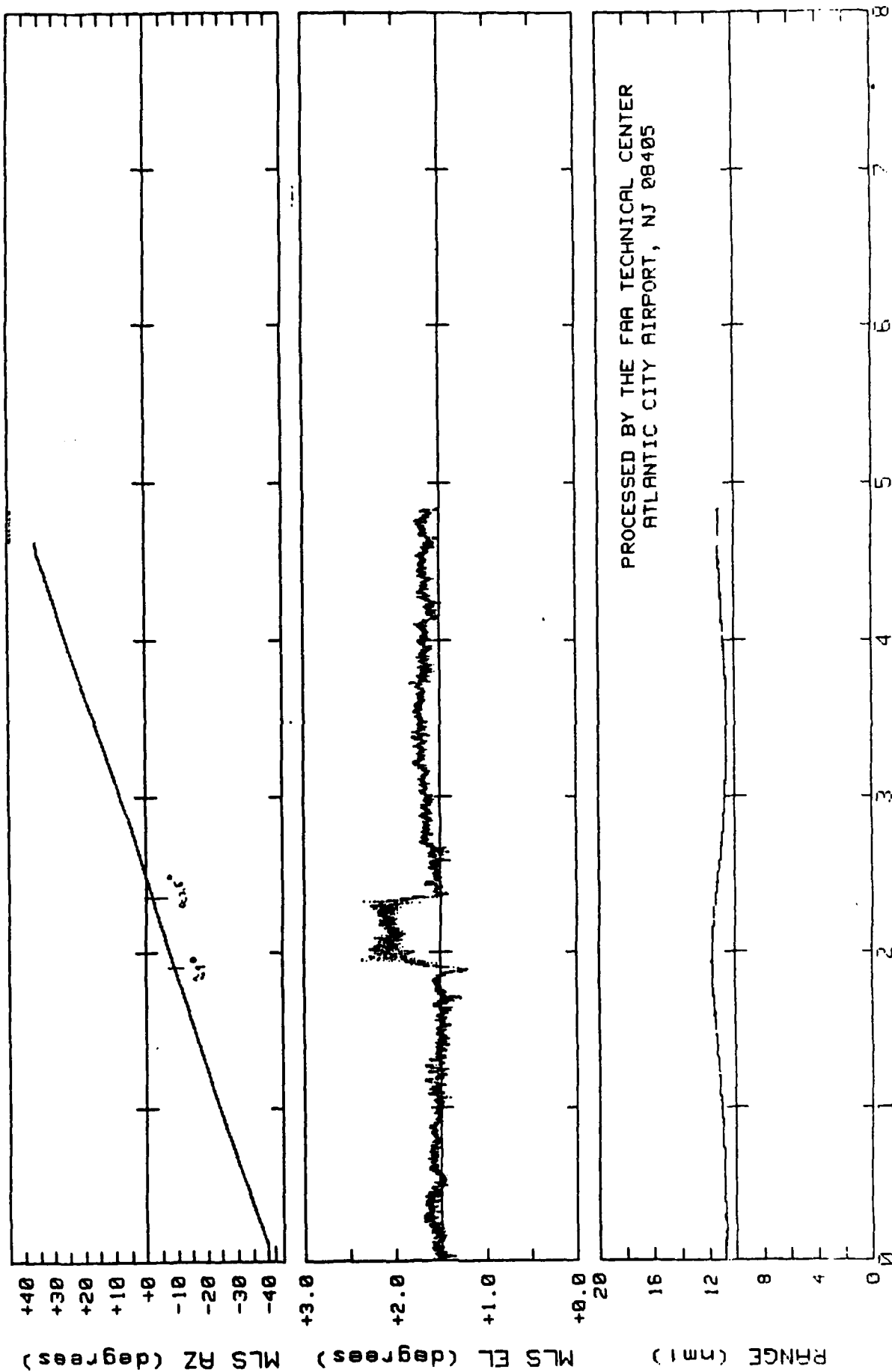


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ATLANTIC CITY AIRPORT, NJ 08405

FIGURE 17. PARTIAL ORBIT AT ELEVATION ANGLE OF 3.6 DEGREE

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL

DATE 8-27-88 TIME 6:26:26 11 nmi DME PARTIAL ORBIT

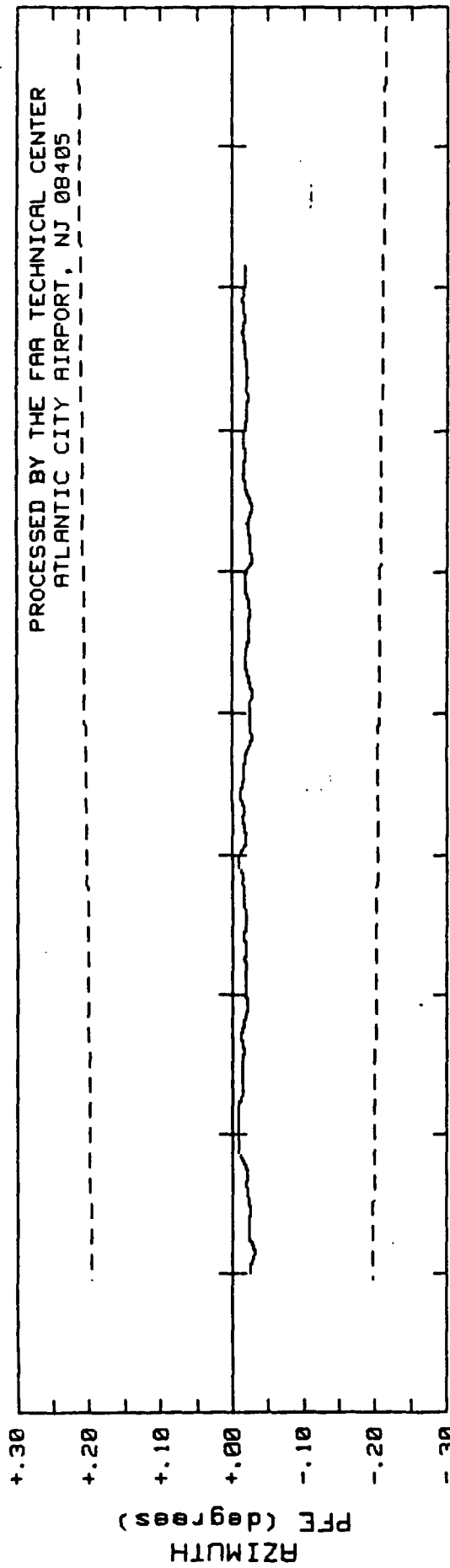


PROCESSED BY THE FAR TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NJ 08405

ELAPSED TIME (minutes)

FIGURE 18. PARTIAL ORBIT AT ELEVATION ANGLE OF 1.6 DEGREE

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-27-88 TIME 08:07:20 3 DEGREE CENTERLINE APPROACH



25

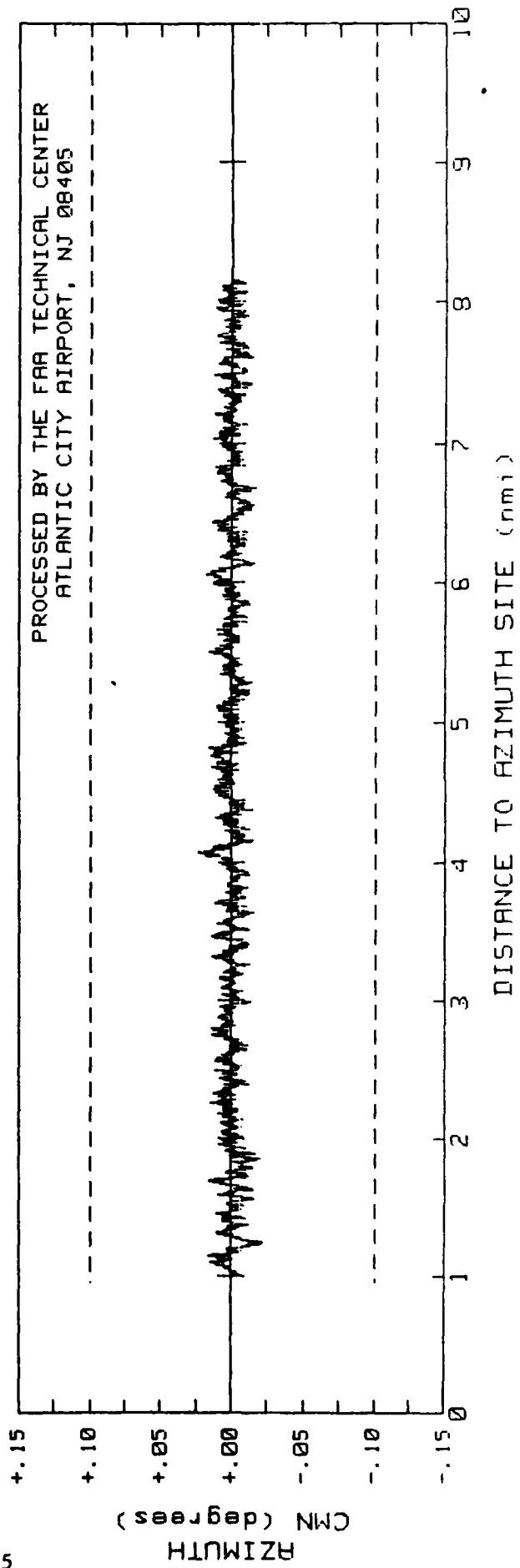
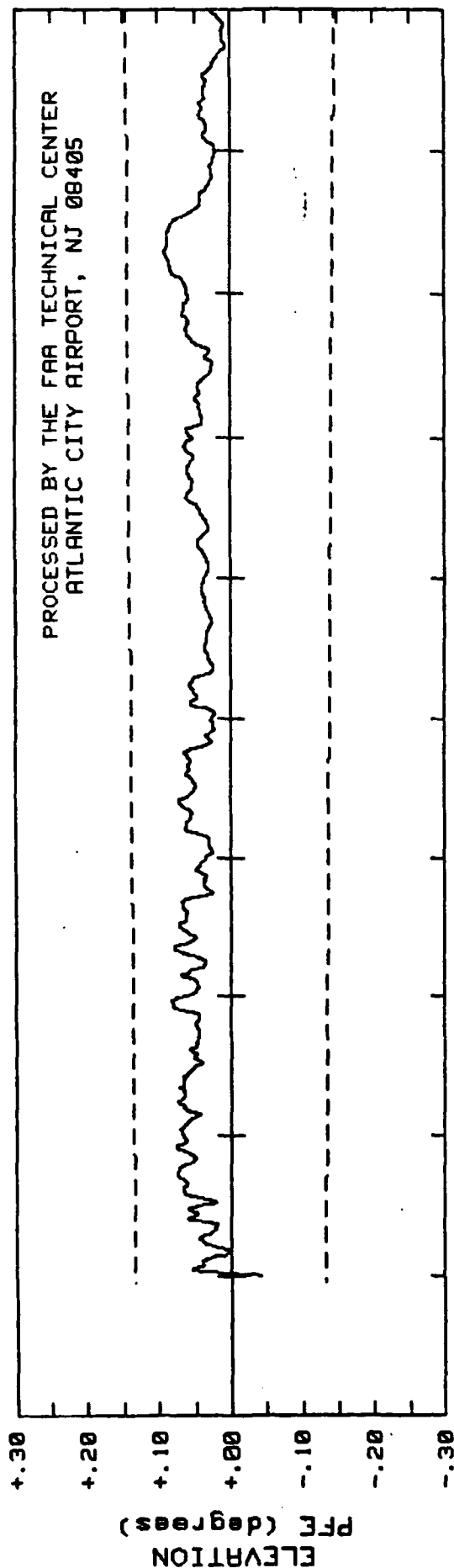


FIGURE 19. AZIMUTH PFE AND CMN FOR 3 DEGREE CENTERLINE APPROACH

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-29-88 TIME 08:16:40 3 DEGREE CENTERLINE APPROACH



26

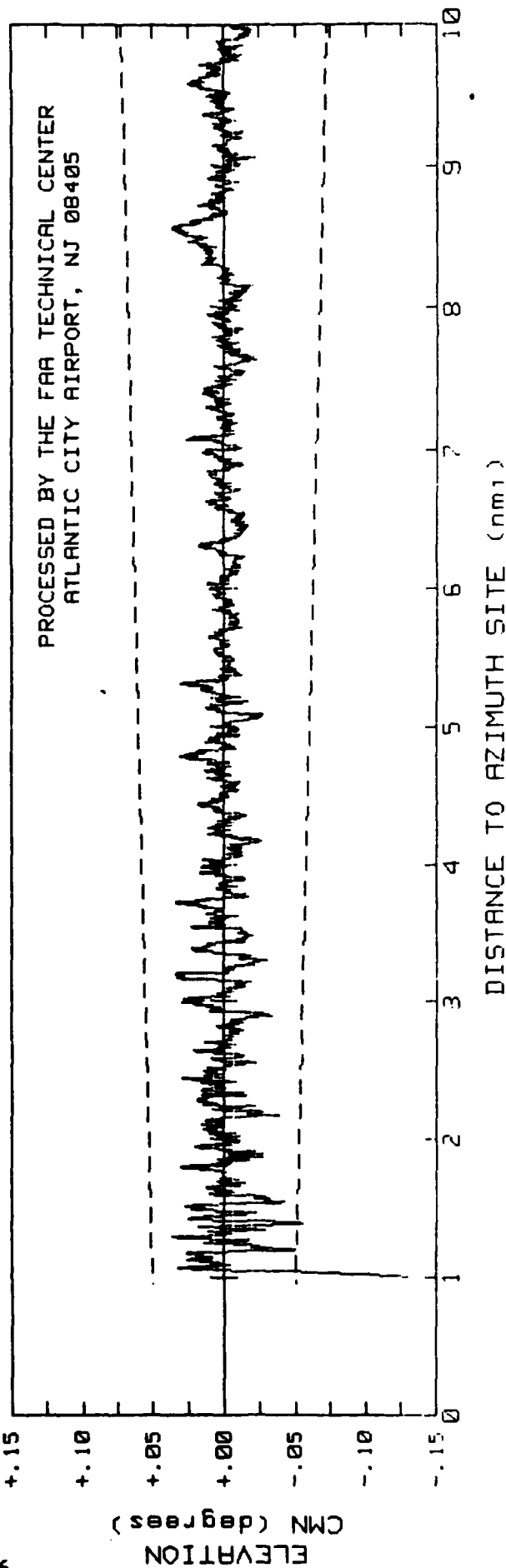
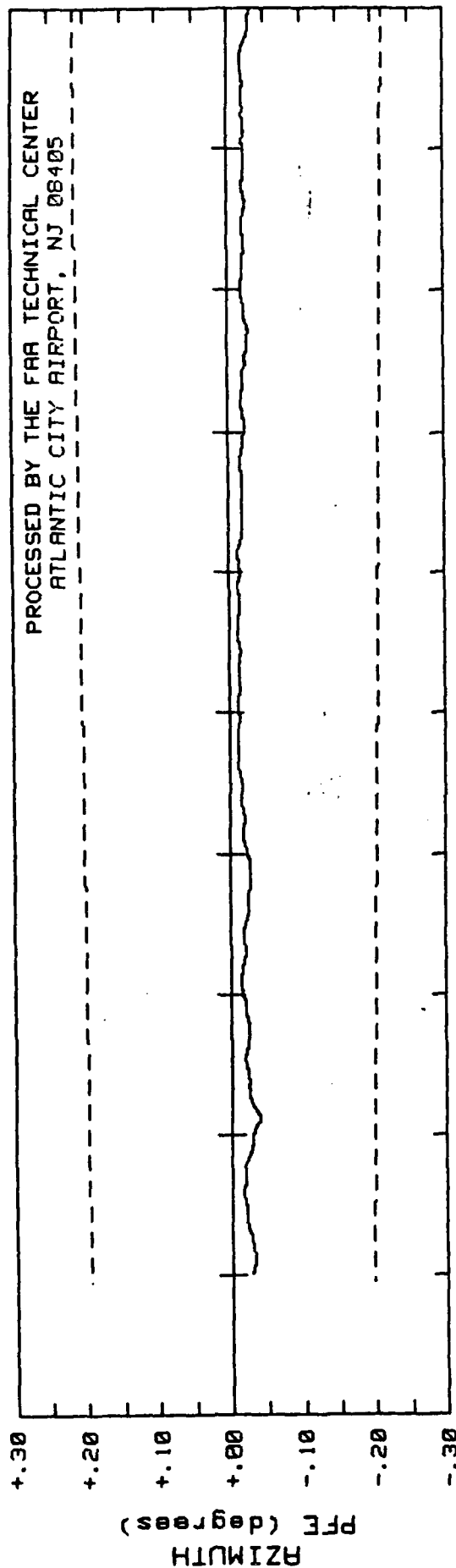


FIGURE 20. ELEVATION PFE AND CMN FOR 3 DEGREE CENTERLINE APPROACH

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-27-88 TIME 07:34:40 3.4 DEGREE CENTERLINE APPROACH



27

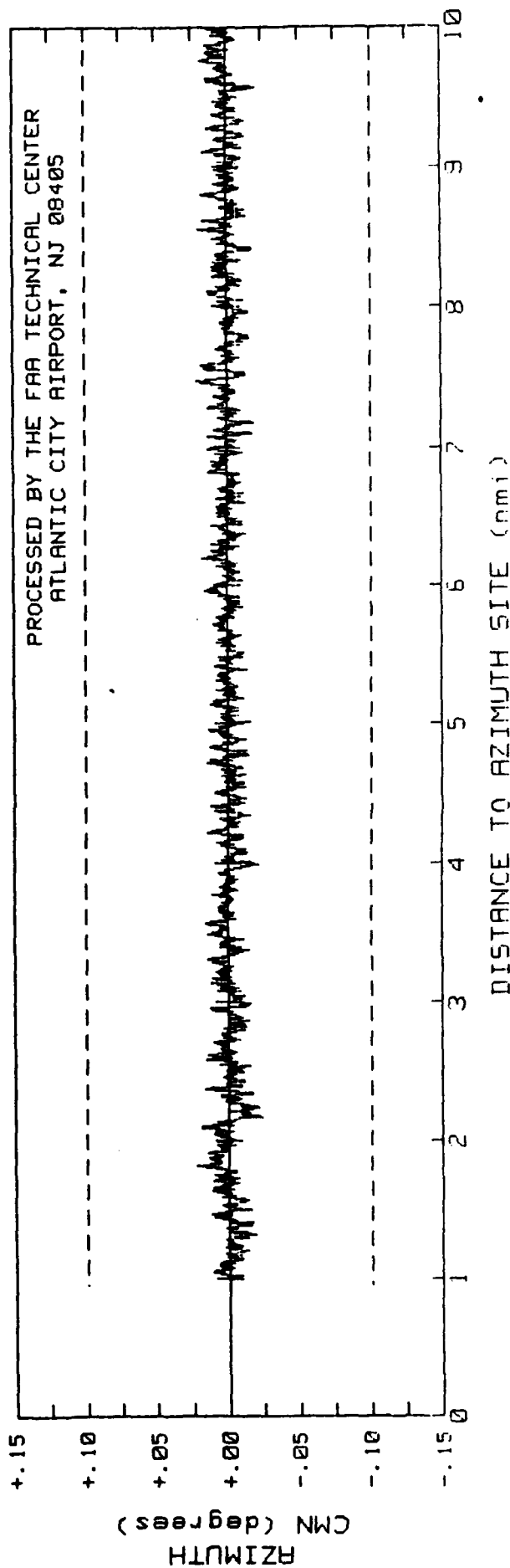


FIGURE 21. AZIMUTH PFE AND CMN FOR 3.4 DEGREE CENTERLINE APPROACH

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-29-88 TIME 06:54:01 3.4 DEGREE CENTERLINE APPROACH

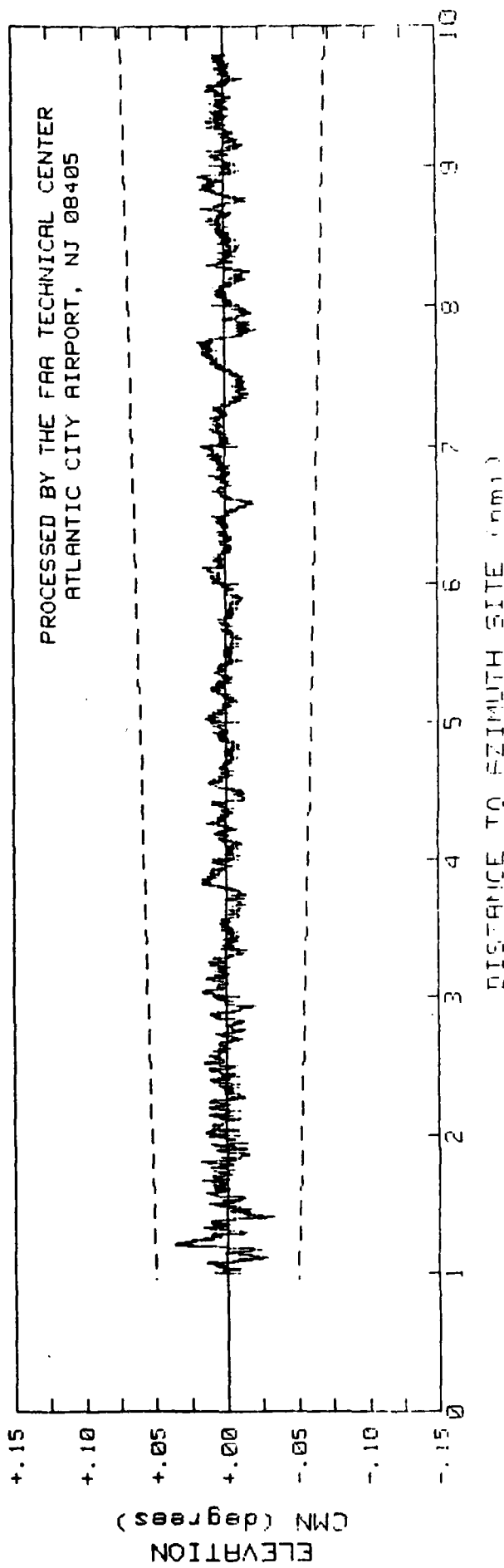
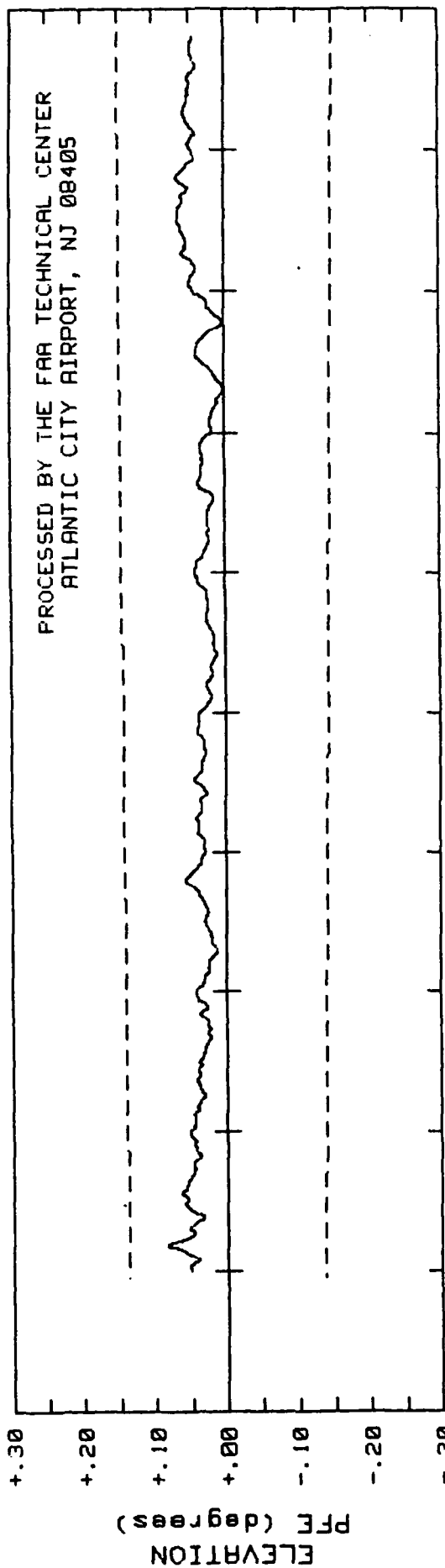
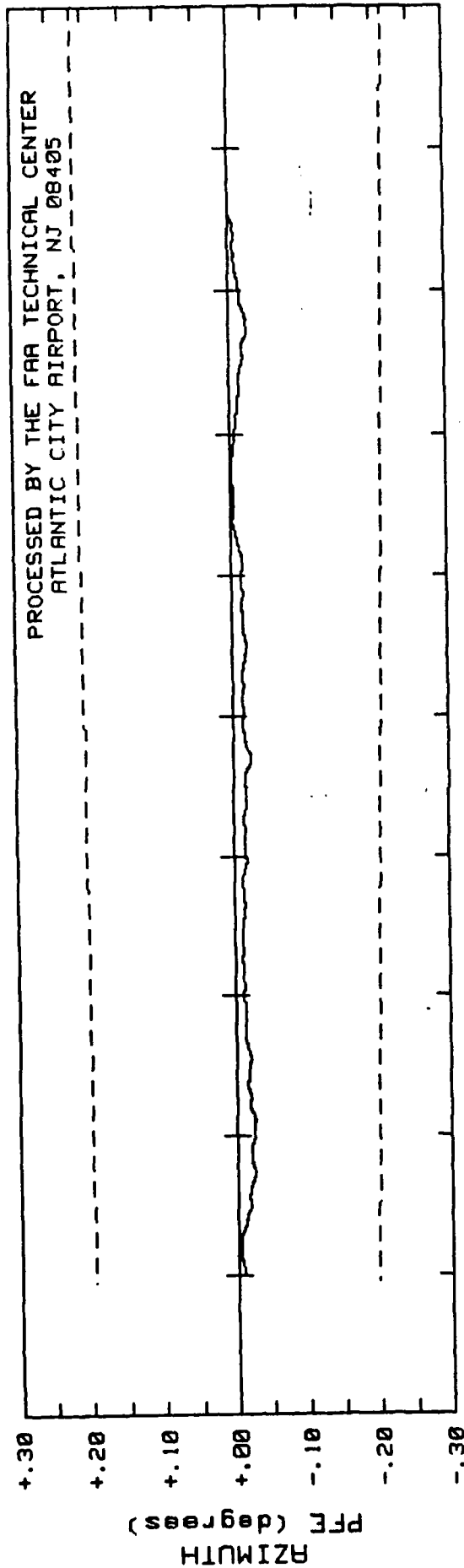


FIGURE 22. ELEVATION PFE AND CMN FOR 3.4 DEGREE CENTERLINE APPROACH

FAR MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-27-88 TIME 06:53:17 3.6 DEGREE CENTERLINE APPROACH



29

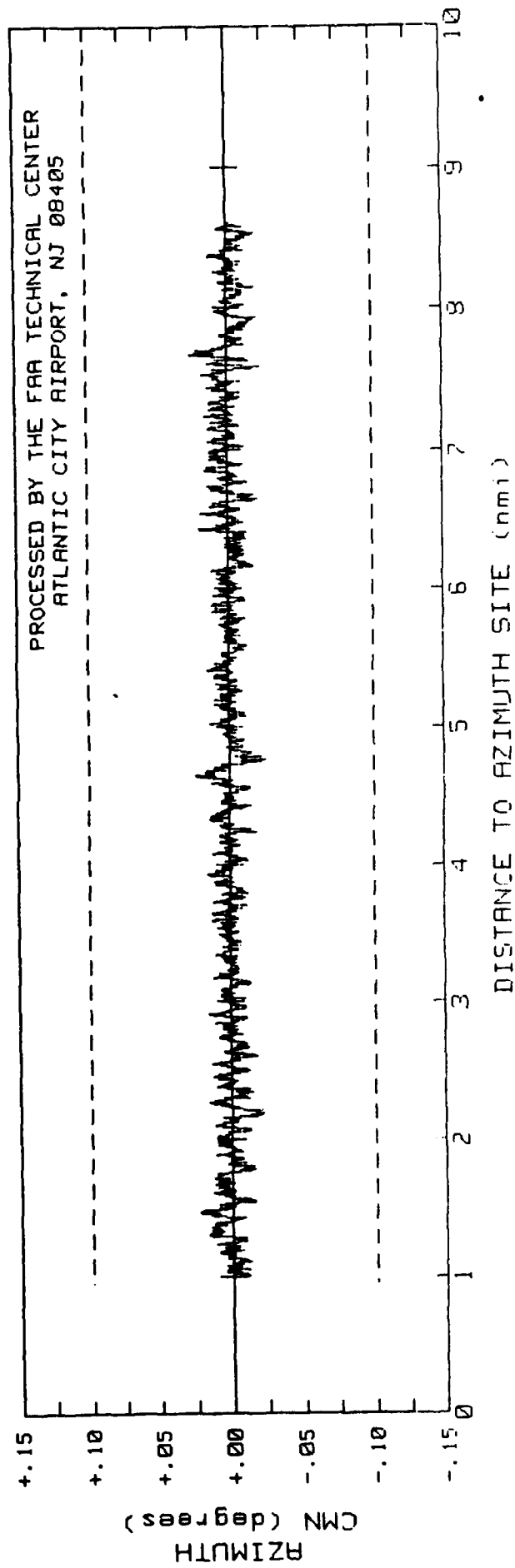


FIGURE 23. AZIMUTH PFE AND CMN FOR 3.6 DEGREE CENTERLINE APPROACH

FAA MLS FLIGHT TEST AT MIDWAY AIRPORT, CHICAGO, IL DATE 8-29-88 TIME 06:44:10 3.6 DEGREE CENTERLINE APPROACH

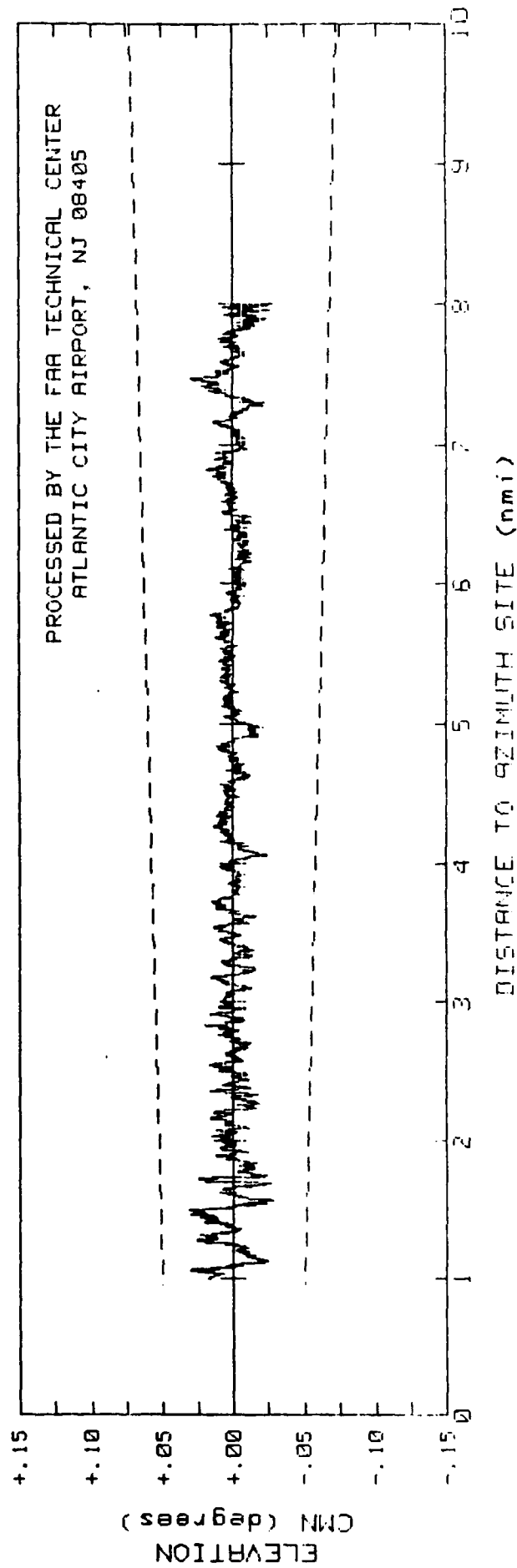
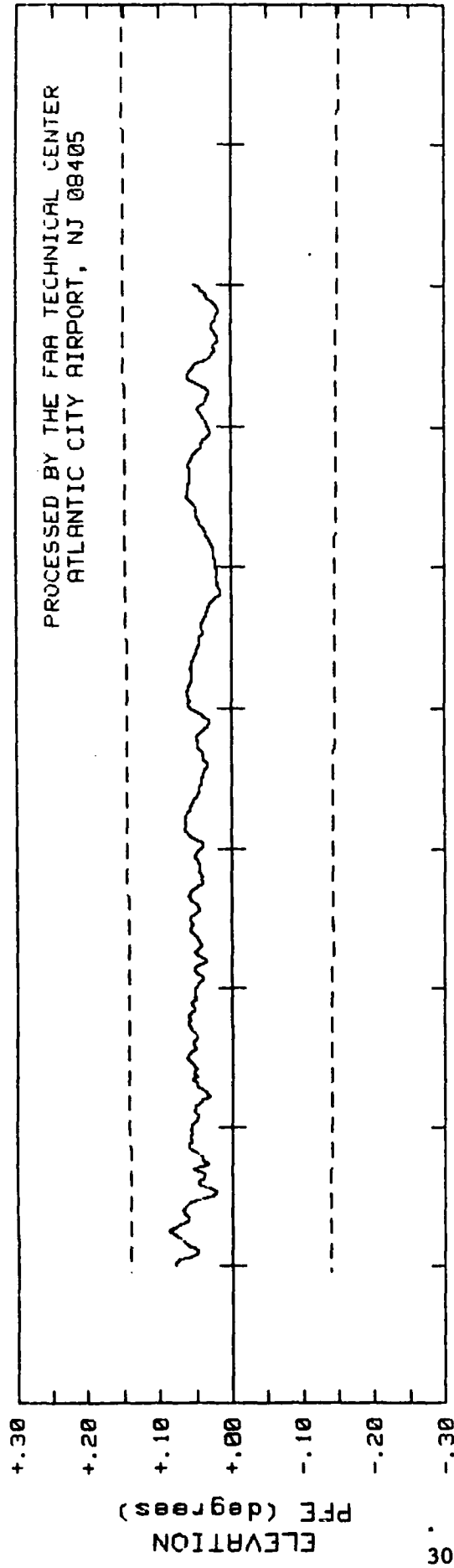


FIGURE 24. ELEVATION PFE AND CMN FOR 3.6 DEGREE CENTERLINE APPROACH

PROFILE #1
3.0° G/S CENTERLINE

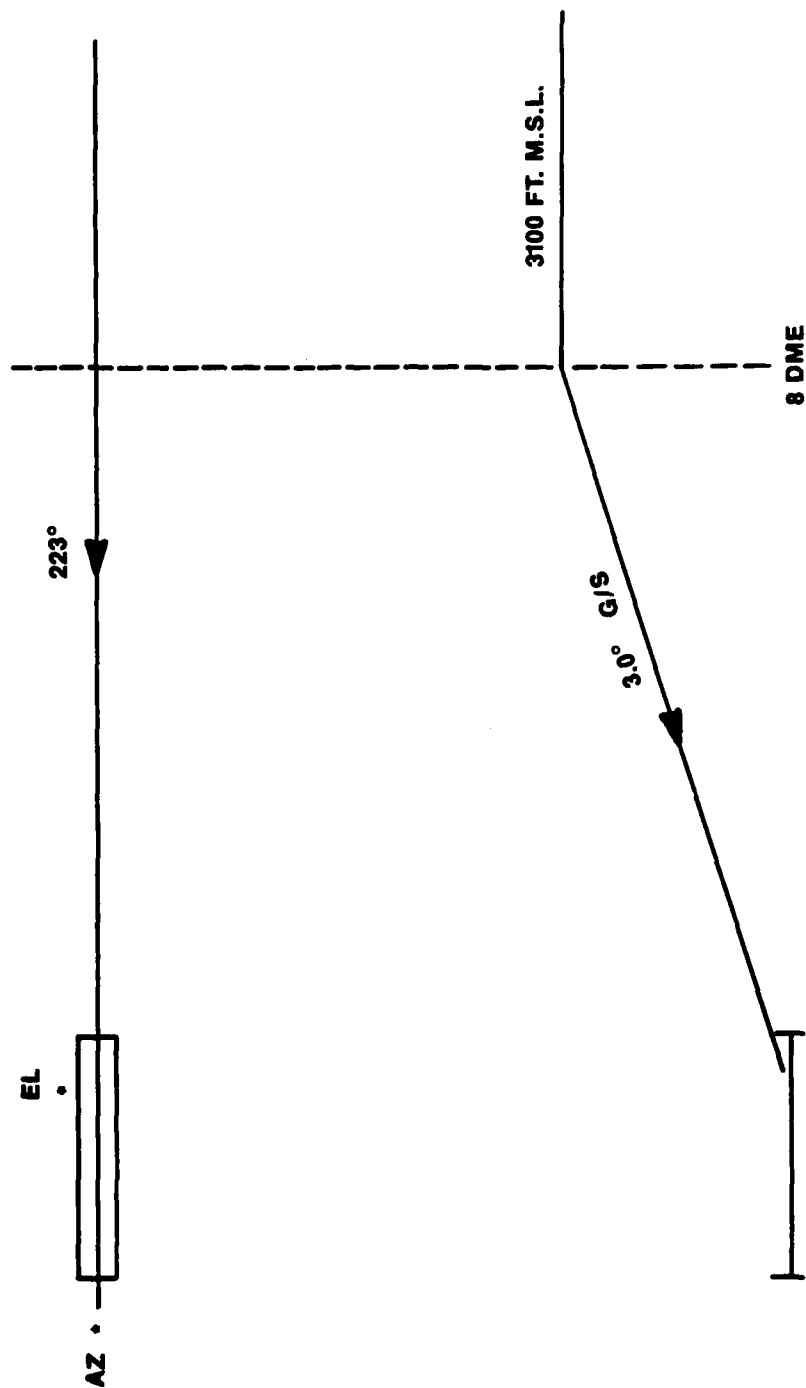


FIGURE 25. DEMONSTRATION PROFILE ONE

PROFILE #2
3.6° G/S TRANSITION TO 3.0° G/S CENTERLINE

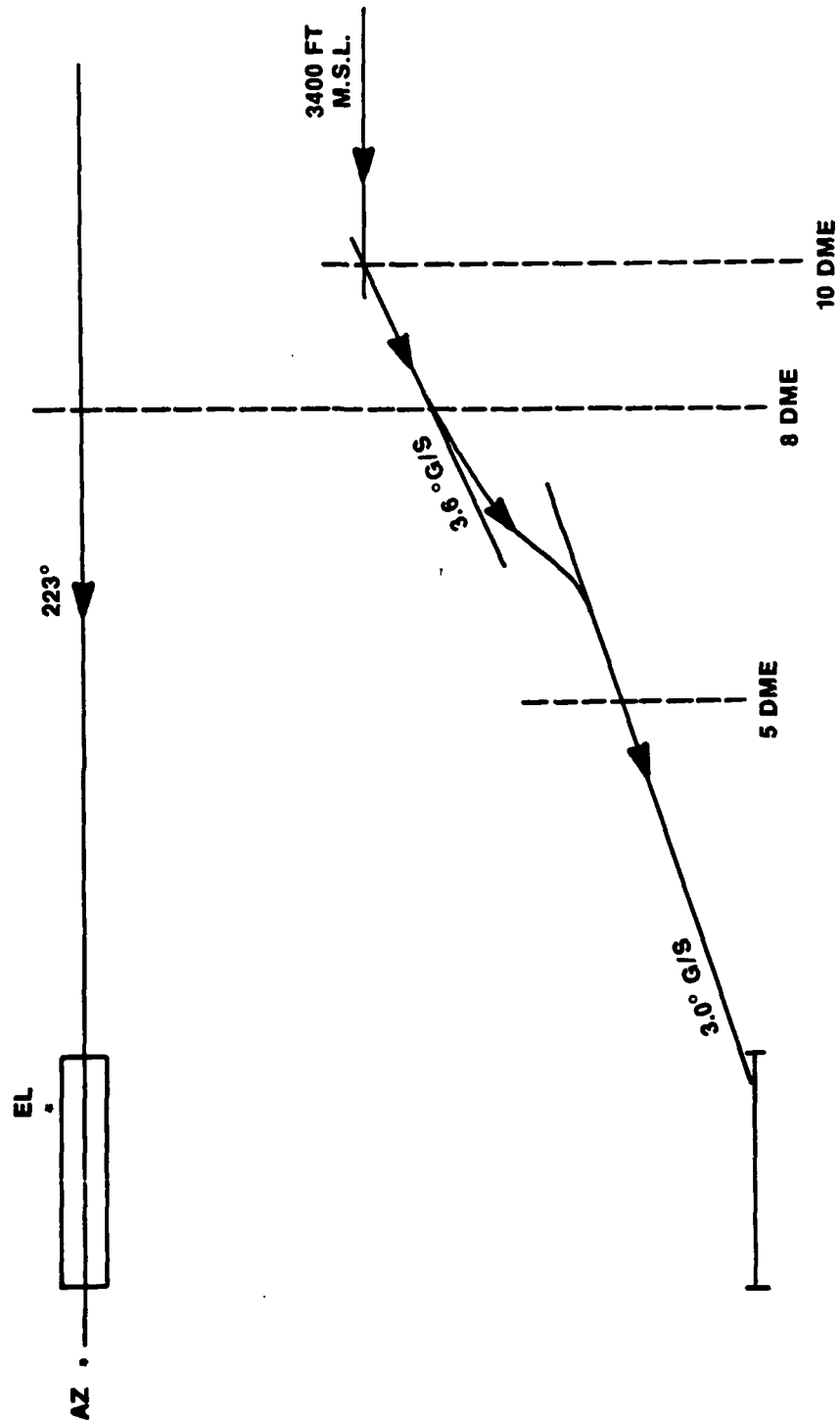


FIGURE 26. DEMONSTRATION PROFILE TWO

PROFILE #3
3.0° G/S
INITIAL 15° LEFT AZIMUTH RADIAL
DOGLEG TO CENTELINE ON FINAL

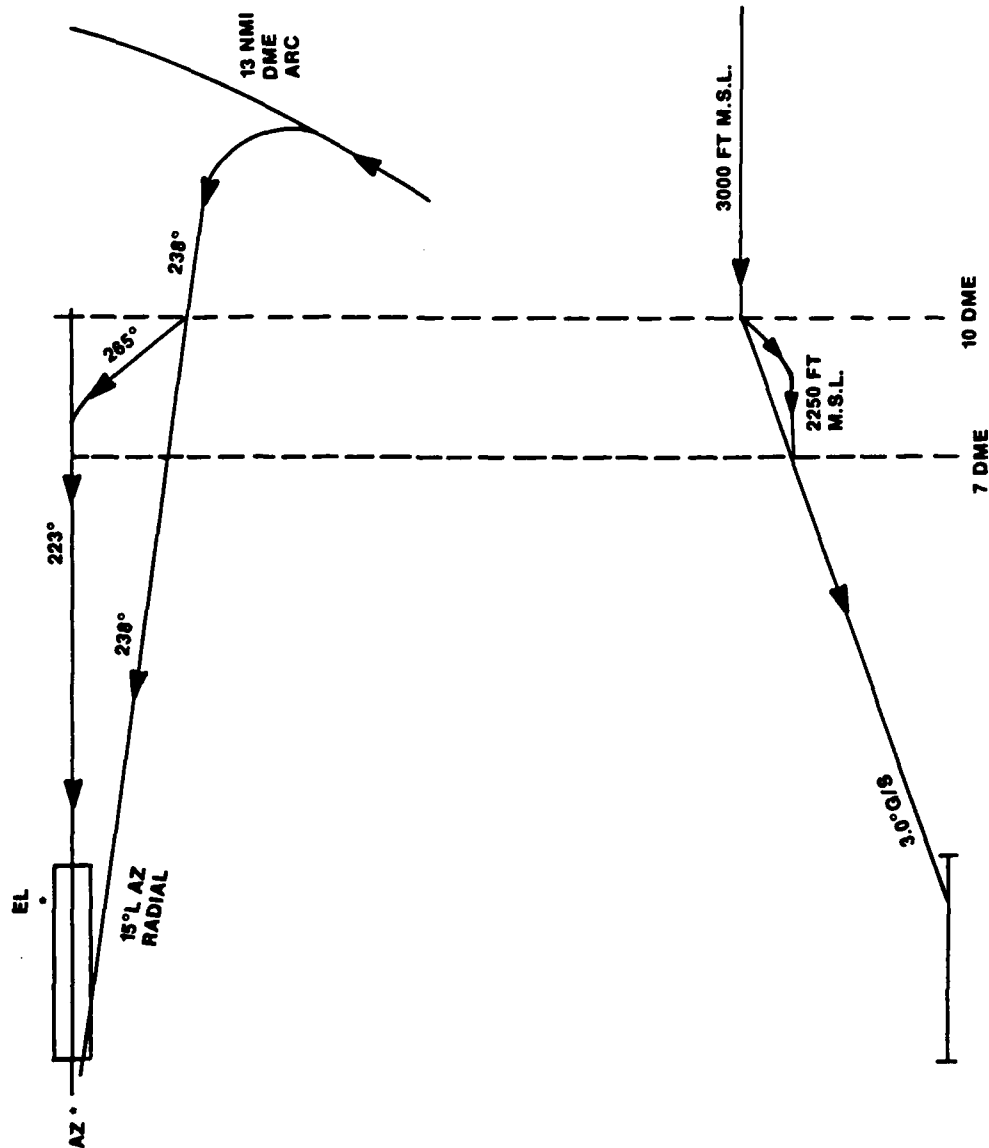


FIGURE 27. DEMONSTRATION PROFILE THREE