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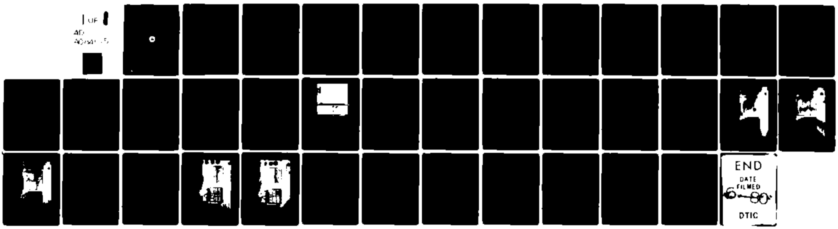

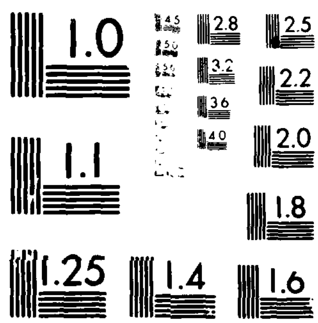

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Report No. FAA-RD-80-18

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FLIGHT EVALUATION OF A RADAR CURSOR TECHNIQUE AS AN AID TO AIRBORNE RADAR APPROACHES

J. Perez

INTERIM REPORT

MARCH 1980

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16. Abstract

This report presents preliminary results of a flight test evaluation of a radar cursor technique to be used as an aid in acquiring and tracking the desired ground track during airborne radar approaches. The test was performed using a Sikorsky CH-53A helicopter on loan from NASA and based at NAFEC. The airborne radar system used was a BENDIX RDR-1400A modified to electronically produce a radar cursor display of course error. Airborne radar approaches were made to an offshore and an airport test environment located within a 60 nautical mile radius of NAFEC. Systems Control, Inc.(SCI), provided contractor services in the areas of test planning, data reduction, and final report preparation. The specific purpose of the test was to evaluate the practical utility of the radar cursor as an aid to performing airborne radar approaches. The preliminary conclusion of this test was that the use of the radar cursor improved course acquisition and ground tracking significantly with pilotage errors and total system cross-track errors reduced by one-half or better. The radar cursor technique showed potential in reducing airspace requirements for airborne radar approaches. SCI is presently completing data reduction and analysis and will publish a final report in the near future.

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METRIC CONVERSION FACTORS

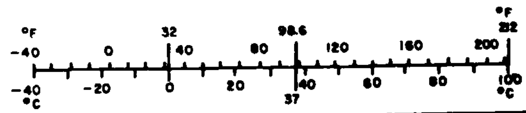
Approximate Conversions to Metric Measures

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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INTRODUCTION

This airborne radar approach (ARA) flight evaluation using a radar cursor technique is a continuation of helicopter ARA inflight experimentation. The overall ARA test program was established to evaluate the operational utility and technical performance of an airborne weather/mapping radar system as an approach-to-landing aid at both on-shore and offshore sites.

The flight evaluation contained in this report is a supplemental effort established to evaluate an airborne radar system modified to electronically produce a radar cursor. The purpose of the cursor is to provide the radar operator with orientation guidance relating to aircraft position and heading, desired course, and target location. The cursor was developed for use in acquiring and maintaining the desired ground track during airborne radar approaches.

This interim report on the cursor technique evaluation provides subjective and preliminary test results. Data reduction and analysis are presently being completed by Systems Control, Inc. (SCI). More detailed statistical information will be contained in the final report to be written by SCI.

PURPOSE.

The purpose of the overall ARA test program, as detailed in report No. FAA RD-79-99, entitled "Airborne Radar System Flight Test Experiment," is twofold:

1. To acquire a statistically reliable data base concerning overall ARA system performance and operational procedures that will assist the Federal Aviation Administration (FAA) and airspace users in developing and certifying standard approach procedures and associated weather minimums.

2. To quantify specific ARA system performance parameters for use by the Radio Technical Commission for Aeronautics (RTCA) Special Committee 133 (SC-133) and the FAA in formulating ARA equipment performance specifications.

The specific purpose of this portion of the overall test program is to evaluate the practical utility of an electronically produced radar cursor as an aid to performing airborne radar approaches.

BACKGROUND.

The ARA test program was initiated by the Systems Research and Development Service to study the use of airborne weather/mapping radar as an approach and landing aid. Consequent flight tests were performed by ANA-110, Approach and Landing Systems Branch, using a Sikorsky CH-53A helicopter based at the National Aviation Facilities Experimental Center (NAFEC), and test pilots from ANA-640, Flight Operations Branch. SCI provided contractor services in the areas of test planning, data collection/reduction, and final report preparation.

From flight tests conducted between July 1978 and December 1978, a report entitled "Airborne Radar Approach System Flight Test Experiment," No. FAA RD-79-99, dated October 1979, was written for the FAA by Champlain Technology Industries, a division of SCI. The flight tests were flown for ARA accuracy and procedures development in both skin paint with and without the use of passive reflectors and single beacon radar operating modes.

From these initial flight tests and actual airborne radar approaches flown in the Gulf of Mexico, it was observed that operators had difficulty in acquiring and maintaining the desired inbound final approach course. The procedure for acquiring and maintaining ground track produced large flight technical errors and resulted in a tendency to "home." This problem is due primarily to the lack of a course display system similar to a course deviation indicator.

There are several ways to provide a course display system to improve ARA track orientation. A low cost alternative (under $500) using a radar cursor technique was developed at NAFEC to enhance acquisition and tracking capabilities. This technique is based on a minor airborne system modification which relates radar return information directly to both aircraft present position and desired final approach course. The modification generates an additional azimuth cursor on the radar screen which displays the intended approach course bearing relative to aircraft heading.

The NAFEC configuration of the radar cursor technique was tested from July 1979 to August 1979 using the NASA CH-53A helicopter based at NAFEC. Data reduction and analysis are presently being performed by Champlain Technology Industries. Preliminary results are reported herein.

DISCUSSION

A Sikorsky CH-53A helicopter on loan from NASA was used as the test bed aircraft. The Bendix RDR-1400A airborne radar system was used to perform the airborne radar approaches. SCI provided contractor services for test planning, data reduction and analysis, and report preparation.

RADAR CURSOR TECHNIQUE.

The RDR-1400 was modified to provide the capability to test a radar cursor technique. The radar cursor technique is a means to improve track orientation during airborne radar approaches. The modified radar system generated an additional azimuth line or cursor, shown in figure 1 as a dashed line. The cursor represents course error or the difference between the desired course and the aircraft magnetic heading. The desired course is selected on the Horizontal Situation Indicator (HSI), and the resulting course error signal from the HSI is fed into the radar system and displayed as the cursor. The cursor, therefore, represents the intended approach course relative to the aircraft heading which is shown as the center or 0° azimuth line on the radar screen. By situating the cursor over the intended target, the aircraft would be placed on the proper ground track.

In general terms, the cursor represents a path parallel to the desired approach path. Once the aircraft is maneuvered onto the proper approach course, the cursor will split the target return. When the cursor does not intersect the return, the aircraft is off-course, and the angular difference between the target center and the cursor is equal to track angle error. Figure 2A displays a typical off-course indication. This shows the cursor not intersecting the target center and the resulting track angle error. Figure 2B shows the effect of drift on an on-course and tracking situation. The aircraft is on-course but must be flown with a slight crab angle to the left of the desired course due to wind conditions.

Two rules of thumb can be used with the radar cursor technique:

1. The target return should be kept between the cursor and the 0° azimuth line. This will insure interception of the desired final approach course prior to the missed approach point. The greater the angular distance between the return and the 0° azimuth line, the sooner the approach course will be intercepted.

2. Turning in the direction corresponding to the direction from the cursor to the target return will insure the proper direction of turn for course correction.

FLIGHT PROFILES.

Two types of airspace environments were used to test the radar cursor technique; (1) an airport site located in the NAFEC terminal area, and (2) an offshore site located in Delaware Bay using Brandywine Lighthouse as a target (figure 3). These testing sites were also the sites used on previous ARA test flights.

In addition, three types of approach profiles were used. These were a direct straight, an overhead straight, and an overhead offset.

A direct straight, shown in figure 4, is a profile in which the descent-to-landing or subsequent missed approach is made on the same initial approach course. The approach descent from 1,000 to 500 feet is initiated at 5 nautical miles (nmi) from the target. Then at 2 nmi, descent from 500 feet to 200 feet is made. The missed approach point is 1/2 nmi from the target. This type of profile would be useful when an upwind initial approach course is flown and obstruction clearance permits descent to the minimums stated.

In an overhead straight profile, shown in figure 5, the pilot flies over the target at 1,000 feet, flies 2.5 minutes (approximately 5 nmi) past the target on the same initial approach course, then reverses direction and performs the same descent procedures as in the direct straight profile. If the aircraft is flown in a downwind direction on the initial approach course, then the overhead straight could be used to situate the aircraft upwind for landing.

In an overhead offset profile, shown in figure 6, the pilot flies over the target at 1,000 feet, flies 2.5 minutes (approximately 5 nmi) past the target on an offset course that would place the aircraft in a downwind condition, reverses direction and performs an upwind descent using the same procedures described above. This profile would allow the pilot to determine his own final approach course based on current wind conditions at the landing site.

In conjunction with the three approach profiles, intentional offset profiles were developed specifically for this phase of testing. These profiles involved intentionally offsetting the aircraft from the desired course at the beginning of an approach to determine the acquisition capability of the cursor technique. The offset distances were based on specific instances of aircraft placement discovered during the analysis of data collected in the initial test phase. Tracking plots of those approaches selected as a base for the intentional offset profiles are shown in figures 7, 8, and 9. Recovery data obtained using the radar cursor will be evaluated against the recovery data shown in figures 7, 8, and 9, obtained without the use of the cursor.

FLIGHT SCHEDULE.

Flight testing was scheduled to consist of approximately 20 hours of flying time (10 flights/2 hours per flight). Four independent variables were addressed:

1. Location: offshore site or airport site.
2. Radar mode: beacon or ground mapping (skin paint).
3. Cursor: cursor aided approach or raw radar return approach.
4. Approach profile: direct straight, overhead straight, or overhead offset.

In addition, intentional offset profiles were specifically developed for this phase of testing. Table 1 shows the intended test matrix.

Out of the 10 scheduled flights, six (12 hours) were flown to an offshore site. Each offshore flight consisted of three direct straight approaches using the ground mapping radar mode (skin paint). The first three flights used the standard radar configuration (no cursor) and the next three flights used the cursor modification. The initial segment of the first approach for each flight was flown from a range of approximately 25 nmi to demonstrate the capability of the radar system to satisfy SC-133 maximum range requirement.

The remaining four flights (8 hours) were flown to an airport site (runways 08 and 26 at NAFEC). A transponder beacon was installed at the threshold of runway 26, and all approaches were flown in the radar beacon mode using the radar cursor for orientation. In the first airport flight, four direct straight approaches were made. Only three overhead straight approaches were made in the second flight due to traffic and fuel constraints. In the third flight, the four scheduled overhead offset approaches were changed to a combination of direct straight and overhead straight approaches because of wind conditions and traffic problems. The three intentional offset profiles were flown in the last flight. The first two approaches in this flight used the overhead straight and the last approach used the overhead offset.

Because of excessive ground clutter associated with the airport site, the beacon mode was used for all the approaches to the airport location. A Motorola transponder, model SST-181X-E, was used. All airport data collected during this test will be compared to corresponding data collected during the initial test series (without cursor).

AIRBORNE PROCEDURES.

Of the four subject pilots used in the initial study, only two were available for this supplementary phase. Two pilots per crew were required, and the two pilots alternated as pilot and copilot. The pilots were familiar with ARA and were proficient in using the airborne radar because of the initial ARA test series.

To simulate an Instrument Flight Rule (IFR) condition, the copilot was hooded to block the view outside of the aircraft. The copilot operated the radar system and monitored the cockpit instruments. Using the information from the radar display and the cockpit instrumentation, the copilot gave heading vectors, necessary airspeed and altitude changes, and range information to direct the pilot toward the target according to the approach profile selected. The pilot was not hooded for safety reasons and performed the necessary flight control actions as instructed by the vectors received from the copilot. The pilot also had the responsibility of handling all communications.

DATA COLLECTION.

The airborne instrumentation consisted of a Litton LTN-51 Inertial Navigation System and a Datametrics SP-380 time code generator interfaced via an aircraft systems coupler to a Norden PDP-11/34M digital computer system. A Norden M2-RX11-DB dual floppy disk system was used for bulk storage. The following parameters were recorded on floppy disks: time, latitude, longitude, ground speed, true heading, and track angle.

In addition to recording inertial position data, the radar screen was photographed along with a digital display of time, date, and aircraft magnetic heading. The photographic recording rate was one frame every 2 seconds. The film data provided simultaneous recording of many parameters, such as time, heading, beacon position relative to the radar cursor or the zero azimuth, scale, sweep, tilt, and gain.

The ground reference data were obtained using the Extended Area Instrumentation Radar (EAIR). The EAIR facility was used as the indicator of actual aircraft position by using it to detect and record the azimuth, elevation, and range of the test aircraft.

During all flights, a cockpit observer monitored and kept a log of routine and special events that occurred during the flight. The following is a summary of the flight test data recorded during each flight:

1. Elapsed time
2. Aircraft altitude, airspeed, and heading
3. Radar approach distance
4. Radar mode, range scale, gain position, tilt and stabilization
5. Pilot workload
6. Procedural errors

After each flight, the pilots completed questionnaires on pilot/copilot workload ratings to evaluate workload on each approach.

DATA PROCESSING.

The airborne and ground-derived position tracking data were used to determine the advantages and disadvantages of the radar cursor technique as an orientation aid in performing airborne radar approaches. To make this evaluation, the following basic groups of measures were computed for each approach:

1. Total System Crosstrack (TSCT) Error - This is the deviation of the aircraft from desired track in the crosstrack direction as measured by the tracking system (EAIR).
2. Airborne System Navigation Error (ASNE) - Crosstrack and along track components of airborne system navigation error are errors due to the combination of radar and heading sensors.
3. Flight Technical Error (FTE) - This is a measure of pilotage error in the cross-track direction.
4. Let Down Error (LDE) - This is a measure of pilotage error in the along track direction at step down fixes.

Data processing was accomplished using a combination of a dedicated microcomputer system resident at the SCI Vermont facility and a remote time-sharing system. Photographic data were processed using a Summagraphics digitizer tablet interfaced with a 32K Byte North Star microcomputer system. The digitized data, along with the parametric data read from each frame (time, heading, scale factor, sweep angle) and keyed in from a CRT terminal, were stored on disks. Once complete files of data for each test were assembled, they were transmitted via dataphone to the Control Data Corporation (CDC) Cybernet System.

The airborne data were then merged with the digitized film data to produce a complete data file from which navigation error measures were derived. EAIR tracking was the primary source of ground reference data, but on some approaches to the offshore site, EAIR tracking was lost due to the low altitude of the test helicopter. When EAIR tracking was lost, INS information was used, in which case a three-way merge was performed. The Cybernet was used to load the INS and EAIR tapes and digitized film data, perform the merge step, and then perform the error measure derivation and statistical analysis steps.

Observer log data along with pilot and copilot workload ratings were also evaluated for each approach.

PRELIMINARY TEST RESULTS

Data reduction and analysis are still being performed at SCI. The details presented in this section were obtained from EAIR plots, pilot/observer comments and logs, and some preliminary statistical information based on data obtained from single beacon airport approaches.

OFFSHORE APPROACHES.

A total of 18 approaches were made to the offshore site. All of the approaches were made using a ground mapping mode (skin paint) of the radar system and the direct straight profile. Nine of the approaches were made without the aid of the radar cursor, and the other nine approaches were made using the cursor technique.

Figures 10 to 12 are photographs of the radar screen and digital display of time, Julian data, and aircraft magnetic heading. Each photograph also shows the radar cursor (dashed azimuth line). Figure 10 shows the difficulty in the skin paint mode of selecting the correct target to track. The target, approximately 25 nmi away and displayed on the 0° azimuth line, is hidden among signal returns from other objects in the bay. The radar screen shows a 120° scan mode which is ±60° each side of the aircraft longitudinal axis.

Figure 11 also depicts the difficult task in locating the correct target even at a range of 14 nmi. The desired ground track for this approach is 232°. Since the target is situated under the cursor, the aircraft is on the proper ground track with a crab angle of 3° to the right (235° aircraft heading).

Figure 12 shows the same approach with the target at approximately 7 nmi. The radar screen was changed to the 40° scan mode which shows ±20° azimuth on the display. The aircraft is on the proper ground track with a crab angle of 6° left. The signal return from a vessel is shown just behind the desired target.

These photographs show that a familiarity with the area is required to correctly identify the target in the skin paint mode. This situation would be similar to locating a specific oil rig in a large cluster of oil rigs when the rigs have approximately identical signal returns. During the course of the test, wrong targets were selected and a few approaches consequently were made to a boat or a different lighthouse.

Figures 13 and 14 show typical EAIR plots of approaches made to the Brandywine Lighthouse. Each figure shows ground tracks of three approaches. The cursor was not used in the approaches shown in figure 13, while the cursor was used for approaches in figure 14.

The first approach in figure 13 (upper left) was flown to a wrong target, again illustrating the problem of target identification. The other two approaches represent fairly good ground track, showing a maximum crosstrack error of approximately 1/2 nmi. The good ground tracks are indicative of the experience gained by the pilots in flying approaches to the same target in the initial ARA test series.

Ground tracks of three approaches using the cursor are shown in figure 14. The first approach (upper left) is another instance of selecting the wrong target. The other two approaches show excellent ground track following capability of the radar cursor technique. The maximum crosstrack error shown is approximately 1/4 nmi.

In using the radar cursor, the pilots experienced a learning curve. Cockpit workload for an airborne radar approach is high, with the radar observer performing gain adjustments, antenna tilt and scan changes, range scale changes, target identification, and drift angle calculations. At first, the cockpit workload seemed to have increased with the use of the cursor due to the unfamiliarity with the radar cursor indication. The pilots were not used to the course error display and were uncertain about which direction to vector the aircraft in order to situate the cursor over the target. The problem was compounded with the radar skin paint mode and its inherent problem of target identification. Not only did the pilots have difficulty in initially identifying the target, but they also had problems in re-identifying the target after making a range scale change or after making a large aircraft heading change.

However, after making several approaches, the pilots became comfortable with the cursor technique and realized that the cursor provided useful information. They discovered that the workload decreased significantly with the automatic display of the track angle error and the drift angle required to fly a desired ground track.

Since the pilots were experienced with conventional ILS approaches, the ILS approach was used as a basis for comparison. The pilots commented that airborne radar approaches with the radar cursor were a moderate to high workload compared to ILS approaches. This comment referred mainly to the two-pilot operation required for ARA as compared to the single pilot ILS approach.

SINGLE BEACON AIRPORT APPROACHES.

A total of 14 approaches was made to an airport site. Five approaches were made with the direct straight profile, eight with the overhead straight, and one with the overhead offset. All of the approaches were made in the beacon mode and with the aid of the radar cursor. A single transponder beacon was located at the landing site.

Figures 15 and 16 are photographs of the radar screen and digital display. The photographs were taken on a demonstration approach to runway 13 on a desired course of 128°. Figure 15 shows the aircraft approximately 15 nmi from the target and on the desired ground track with a crab angle of 20° right. This photograph depicts an intercept or acquisition of the desired inbound course.

Figure 16 shows the aircraft on course and approximately 2 1/4 nmi from the target. As can be seen, the beacon signal return is starting to break up. The beacon signal return breaking up and fanning out in azimuth at close range can present a problem of determining where to split the signal with the cursor to maintain proper ground track. This was not a serious problem in this test.

Figure 17 shows EAIR plots of two direct straight approaches made to the threshold of runway 26. The top ground track was flown with a desired course of 082° and the lower plot had a desired course of 262°. These plots show excellent acquisition and tracking performance with minimal deviation from the desired course.

Figure 18 shows EAIR plots of two overhead straight approaches made to the threshold of runway 26. In both approaches, the initial approach course was 082°. The aircraft was flown 5 nmi past the target on this initial approach course after which a procedure turn was made to a final inbound approach course of 262°. Both ground tracks again show excellent acquisition and ground track performance with maximum crosstrack deviation of approximately 1/4 nmi.

Figure 19 is a composite plot of total system crosstrack error of airport beacon approaches made without the use of the cursor. These data were obtained from the initial ARA test series. This plot shows that between 5 and 10 nmi from the beacon, the maximum deviation from the intended track is around 2.5 nmi. This figure is well within the 4 nmi airspace requirement established by the Radio Technical Commission for Aeronautics (RTCA) SC-133 Minimum Operational Performance Standards (MOPS). Within 5 nmi from the beacon, the maximum deviation from the intended course is 1.3 nmi, which is within the required airspace limit of 1.7 nmi at the missed approach point. This limit was set by the SC-133 MOPS.

Figure 20 is a composite plot of total system crosstrack error of airport beacon aproaches made with the use of the cursor. This shows that between 5 and 10 nmi from the beacon, the maximum deviation from the intended track is around 0.75 nmi. Within 5 nmi from the beacon, the maximum deviation is around 0.9 nmi.

Table 2 is a statistical summary of FTE and TSCT errors obtained from the two previous composite plots shown in figures 19 and 20. The total FTE mean without the cursor is around 0.6 nmi as compared to around 0.3 nmi with the cursor. The total TSCT error mean without the cursor is around 0.6 nmi as compared to around 0.2 nmi with the cursor. These data show that the use of the radar cursor had reduced the errors by around 1/2.

Finally, figure 21 shows the significant reduction in FTE and TSCT errors in the final approach segment which can be attributed to the use of the cursor. These graphs show the standard deviations of the errors from 5 nmi to 1 nmi from the target. The errors can be seen to have been reduced by 1/2 or better with the use of the cursor.

More indepth and detailed statistical information is forthcoming in a report from SCI. However, these preliminary results indicate that the airborne radar system with the cursor modification performed quite well. The use of the radar cursor technique showed a significant improvement in course acquisition and ground tracking and shows potential in reducing airspace requirements for airborne radar approaches.

CONCLUSIONS

1. The radar system cursor modification performed well with no failure of the cursor throughout all the flights.

2. Use of the radar cursor showed a significant improvement in course acquisition and ground tracking with Flight Technical Error (FTE) and Total System Crosstrack (TSCT) error reduced by one-half or better.

3. The pilots, who were familiar with airborne radar approaches, required minimal time to adapt to the cursor technique.

4. Use of the cursor facilitated procedure for maintaining crosswind crab. By maintaining the cursor over the target, the pilot automatically flew the desired drift angle for the existing wind conditions.

5. Cockpit workload was reduced but still necessitated two crew members.

6. The skin paint mode provided for obstacle clearance, but offered no positive identification of the site. In contrast, the beacon mode provided positive site identification but no obstacle clearance capability.

7. Large target widths were encountered at close ranges but had no affect on the operational performance of the radar system.

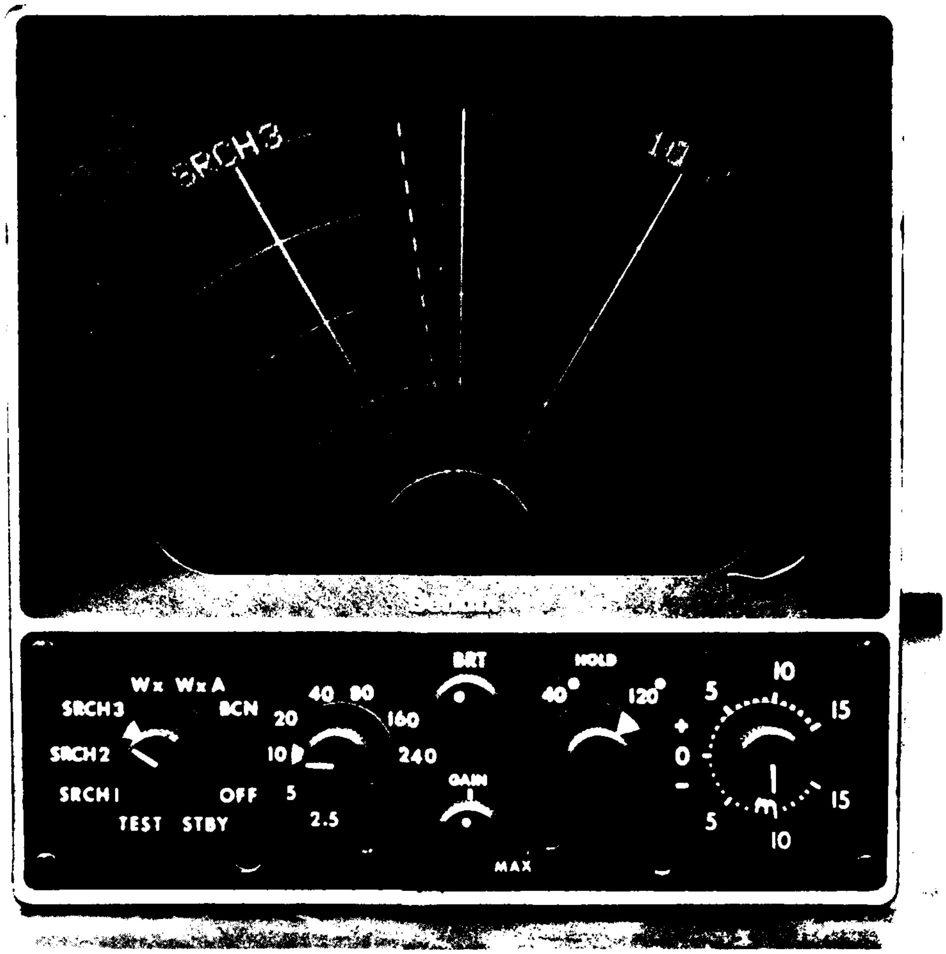


FIGURE 1. BENDIX RDR-1400A DISPLAY SHOWING RADAR CURSOR

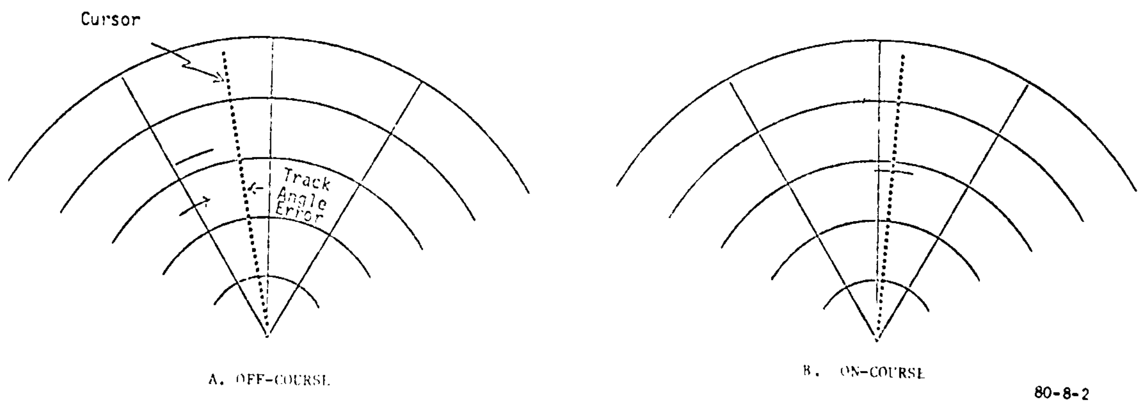


FIGURE 2. RADAR CURSOR TRACK ORIENTATION

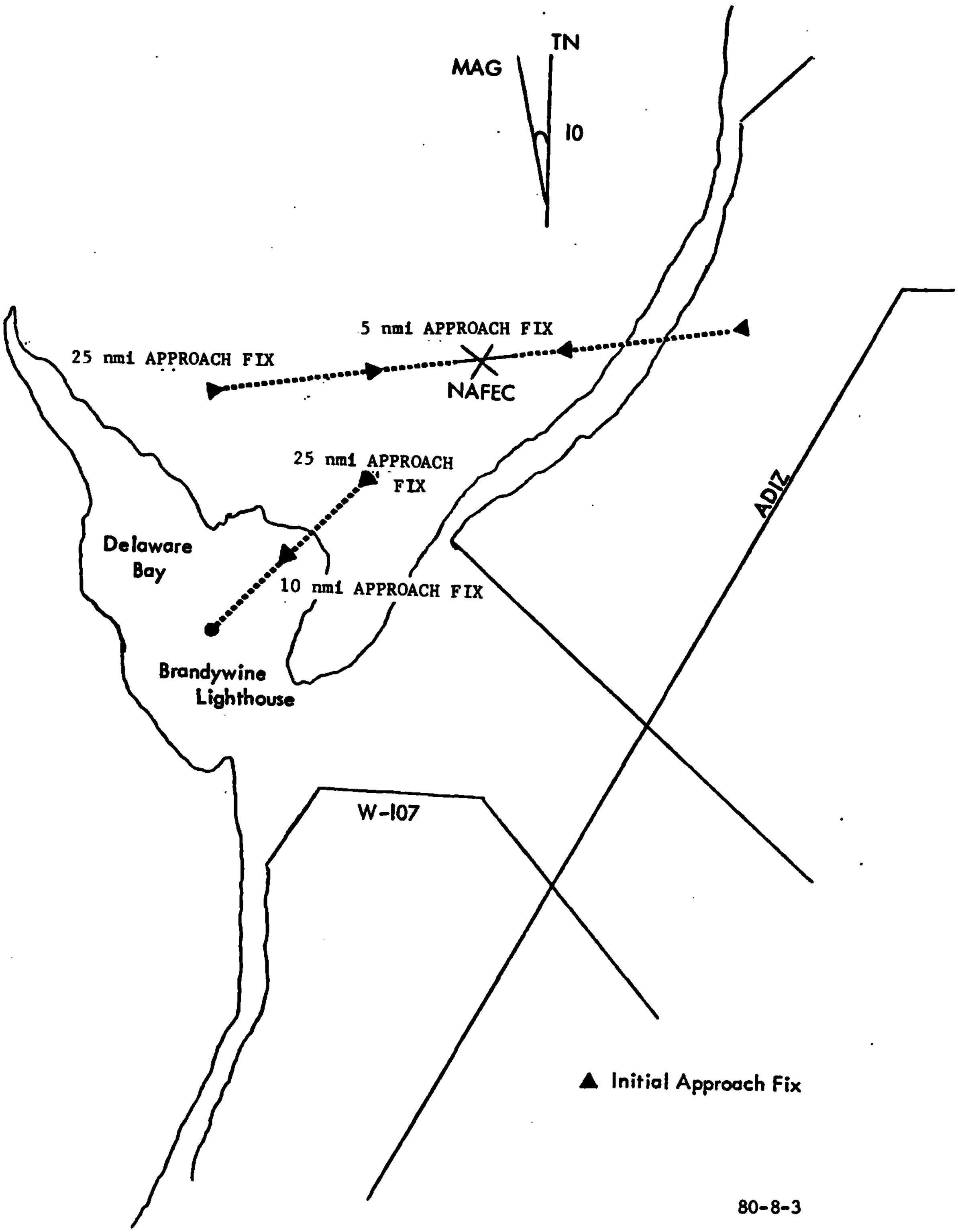


FIGURE 3. AIRBORNE RADAR APPROACH (ARA) GEOMETRIES

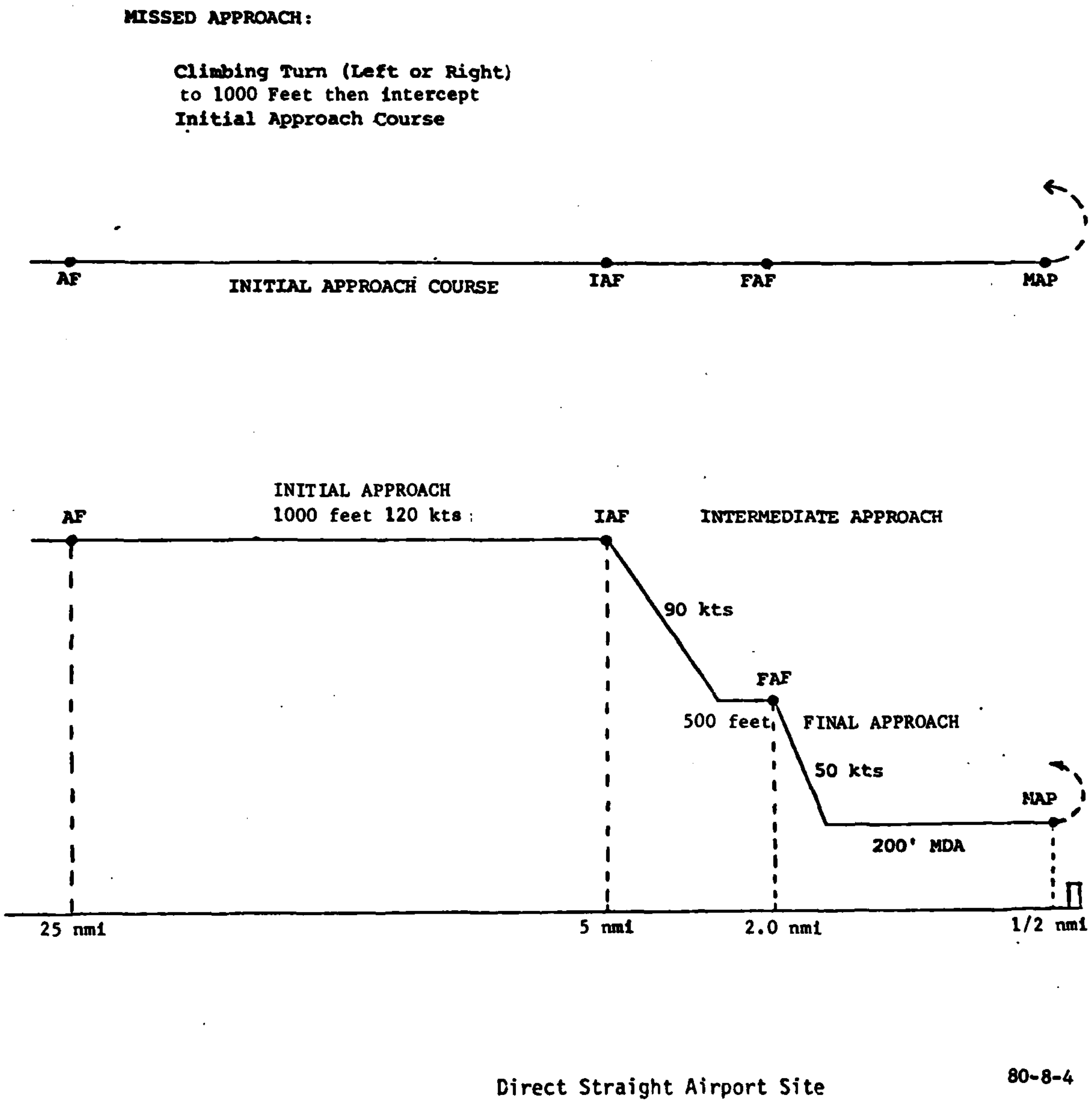
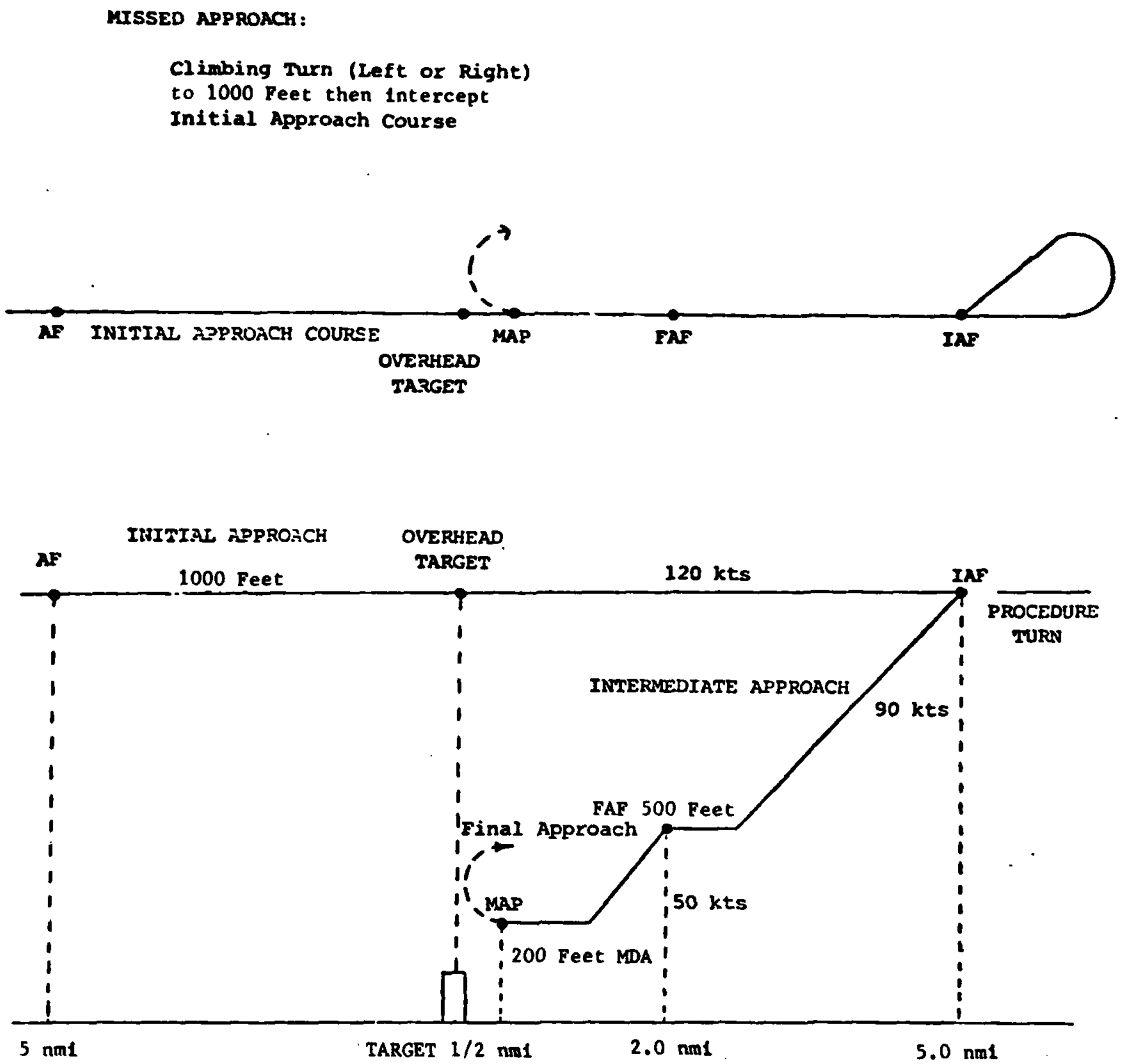


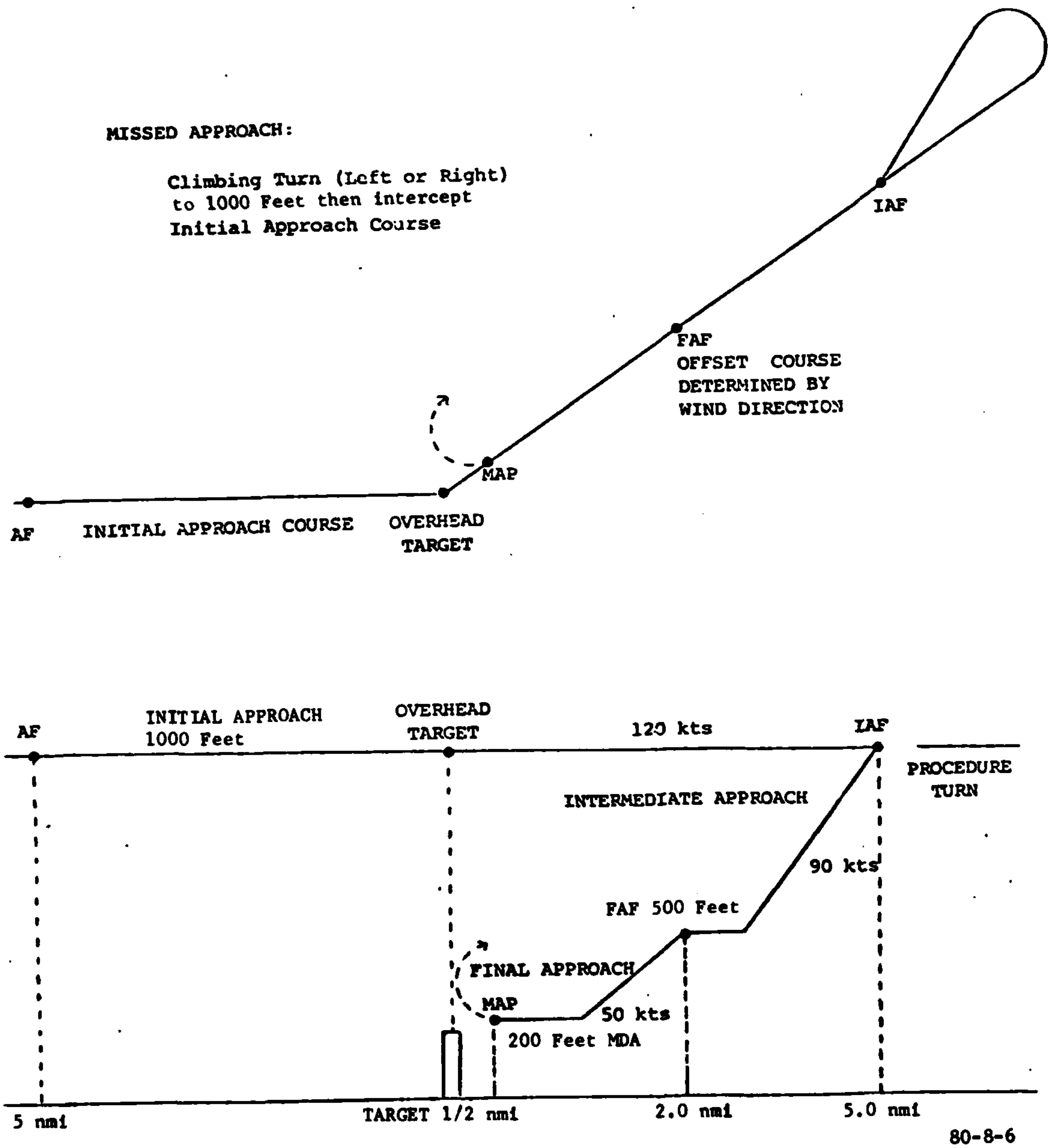
FIGURE 4. DIRECT STRAIGHT PROFILE



80-8-5

Overhead Straight Airport Site

FIGURE 5. OVERHEAD STRAIGHT PROFILE



Overhead Offset Airport Site

FIGURE 6. OVERHEAD OFFSET PROFILE

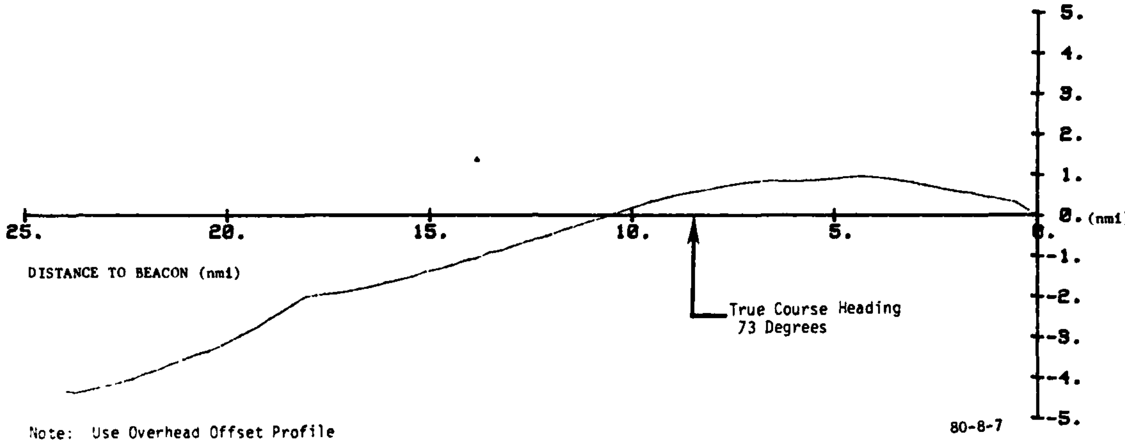


FIGURE 7. INITIAL SEGMENT OF AN APPROACH FLOWN ON NOVEMBER 3, 1978

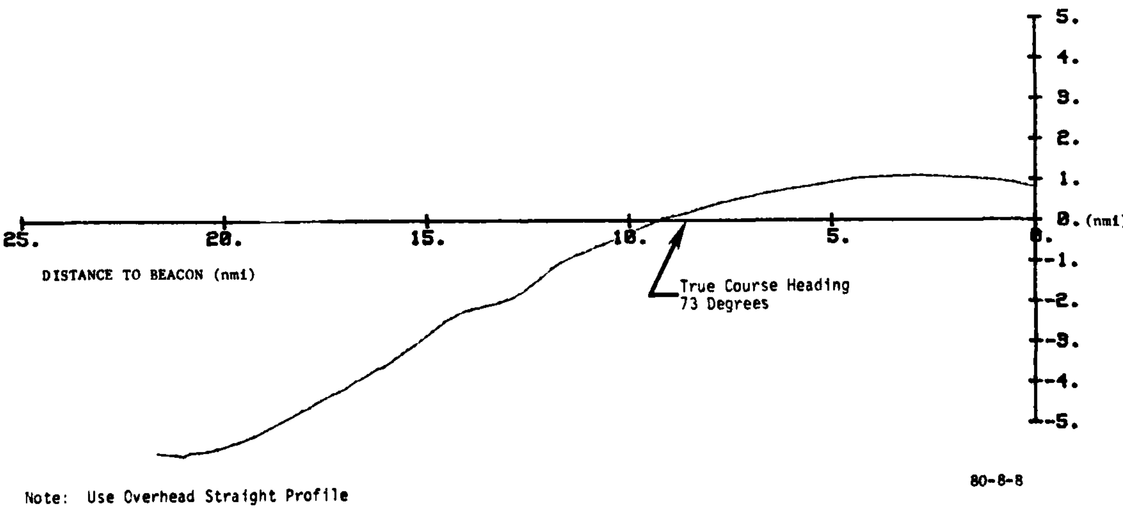


FIGURE 8. INITIAL SEGMENT OF AN APPROACH FLOWN ON DECEMBER 13, 1978

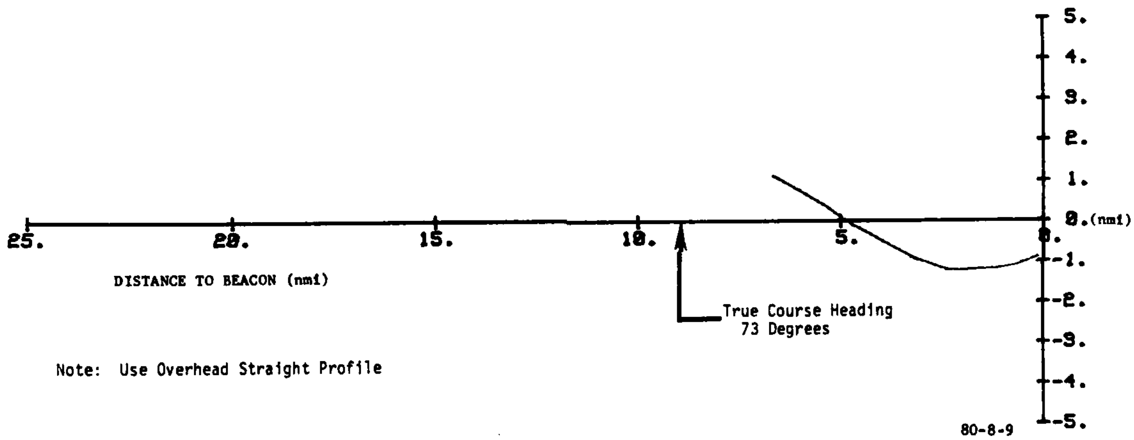


FIGURE 9. INITIAL SEGMENT OF AN APPROACH FLOWN ON DECEMBER 14, 1978

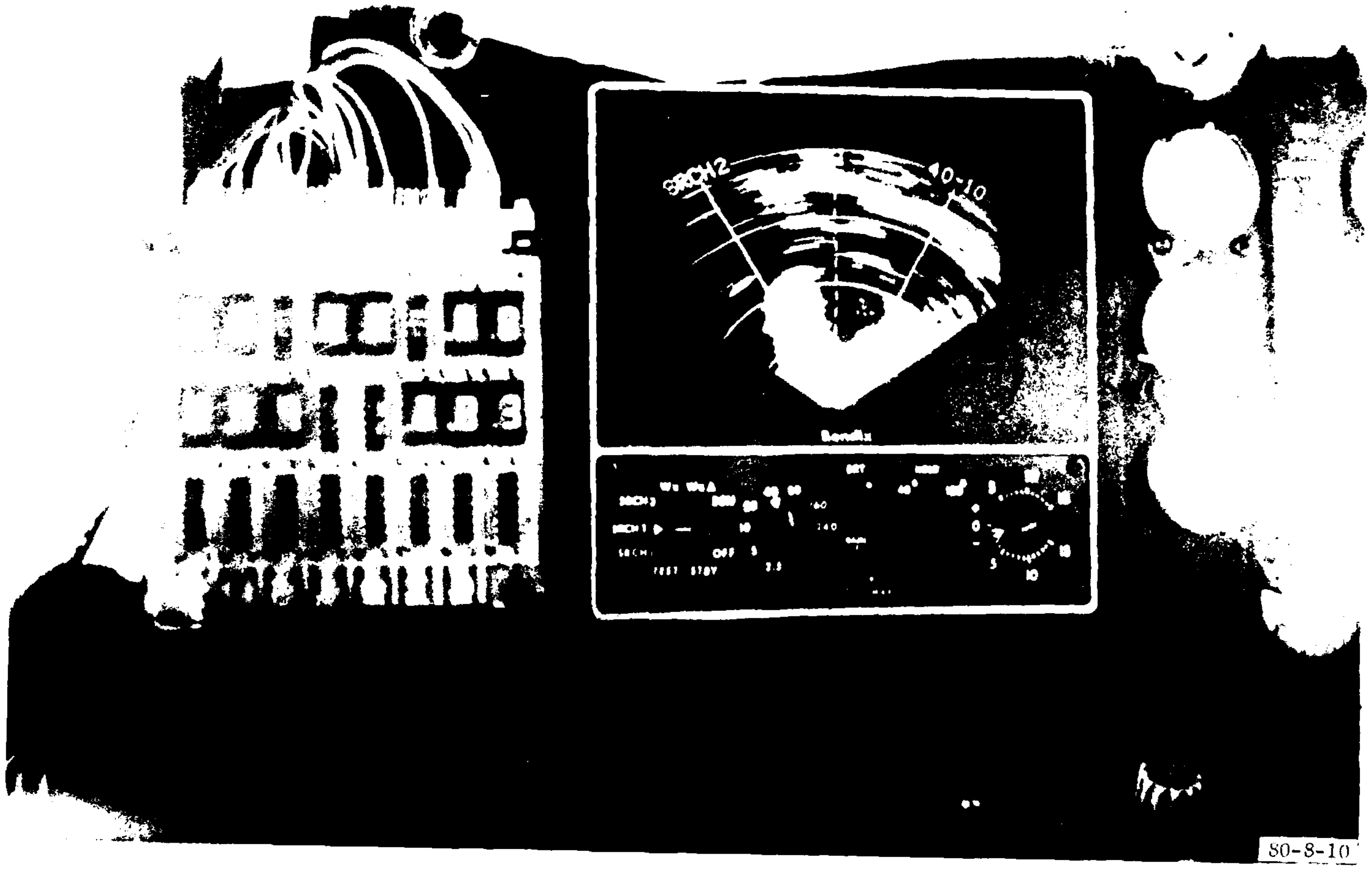


FIGURE 10. OFFSHORE APPROACH, SKIN PAINT TARGET AT 25 nmi

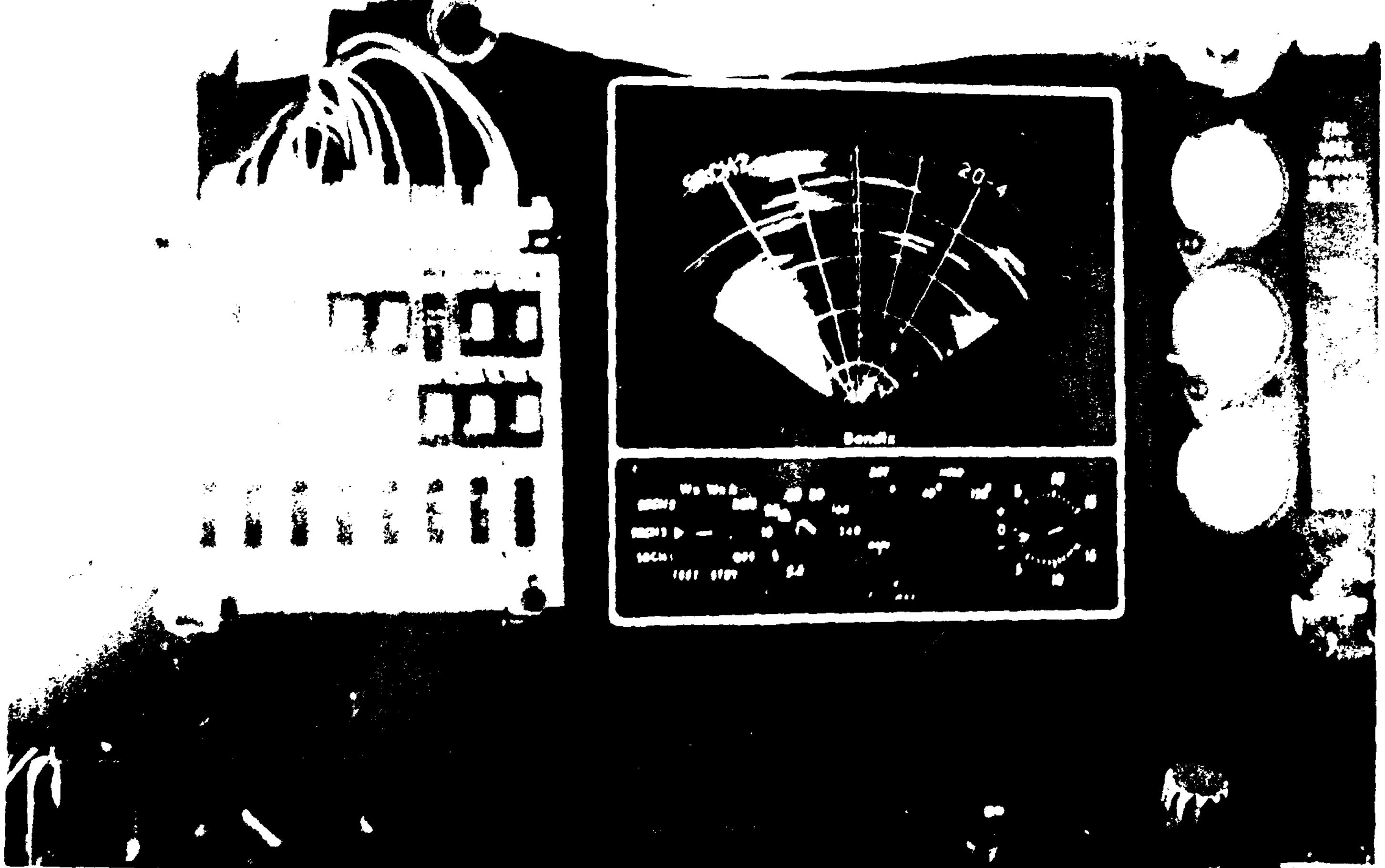


FIGURE 11. OFFSHORE APPROACH, SKIN PAINT TARGET AT 14 nmi

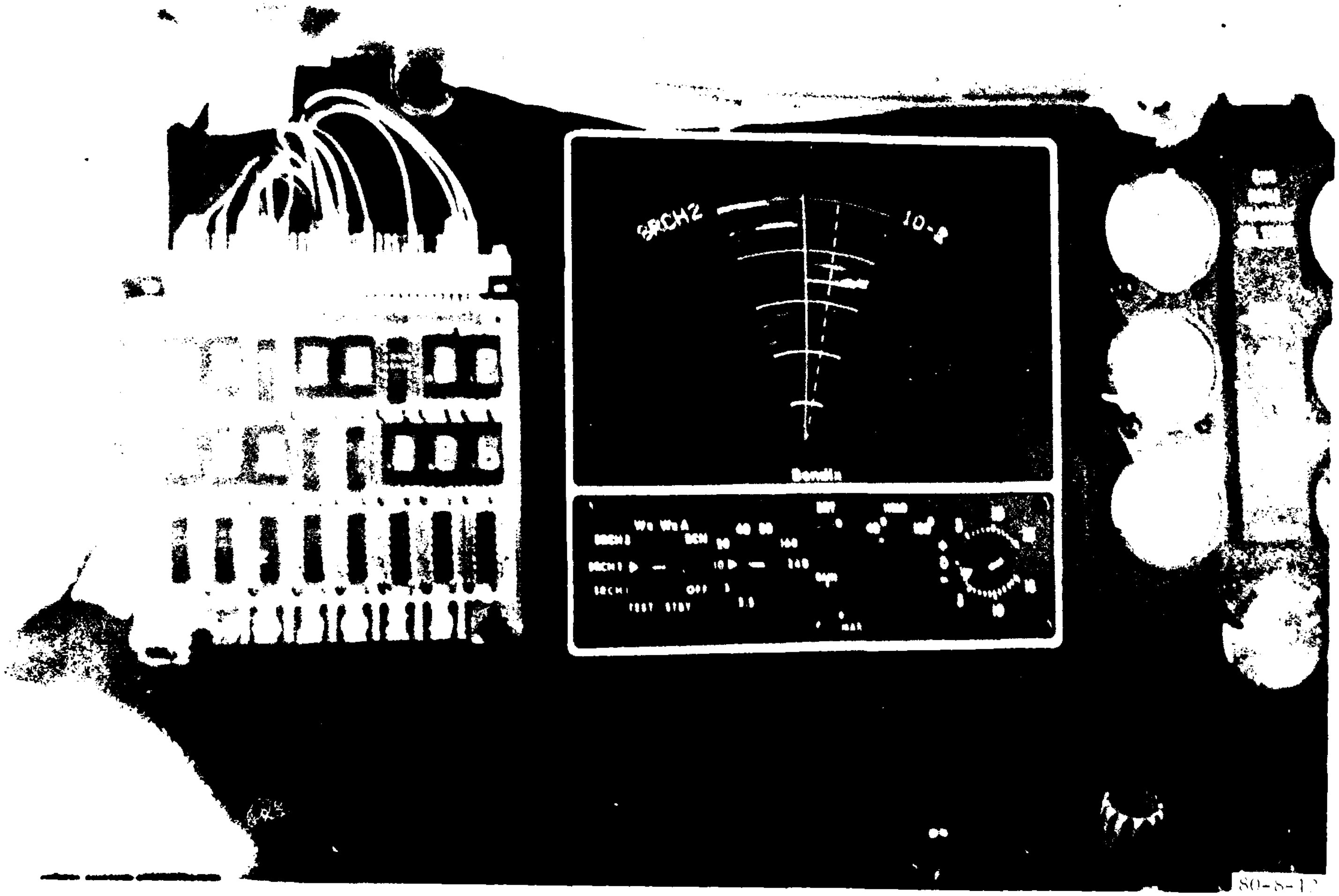


FIGURE 12. OFFSHORE APPROACH, SKIN PAINT TARGET AT 7 nmi

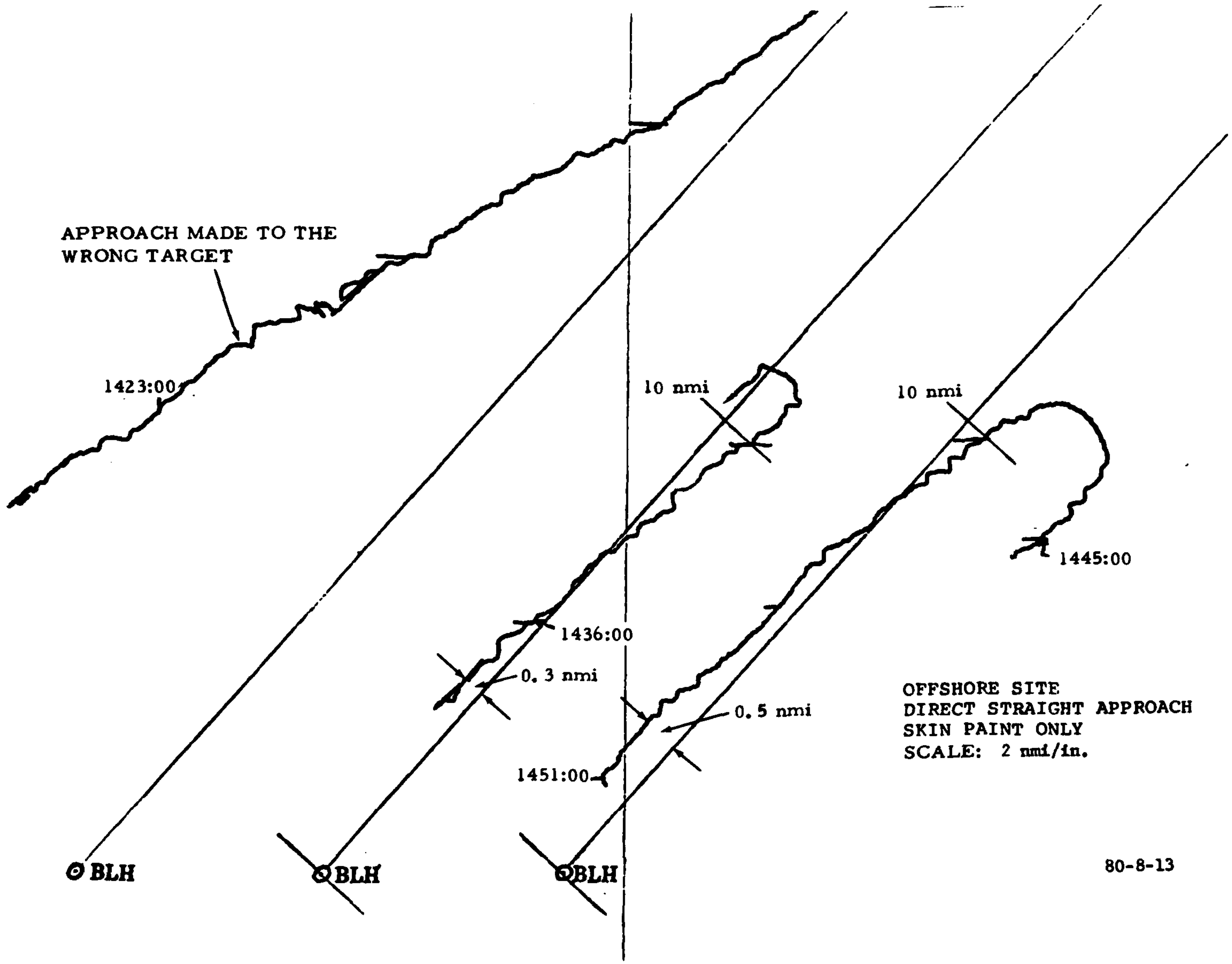


FIGURE 13. EAIR PLOTS OF OFFSHORE APPROACHES (SKIN PAINT ONLY)

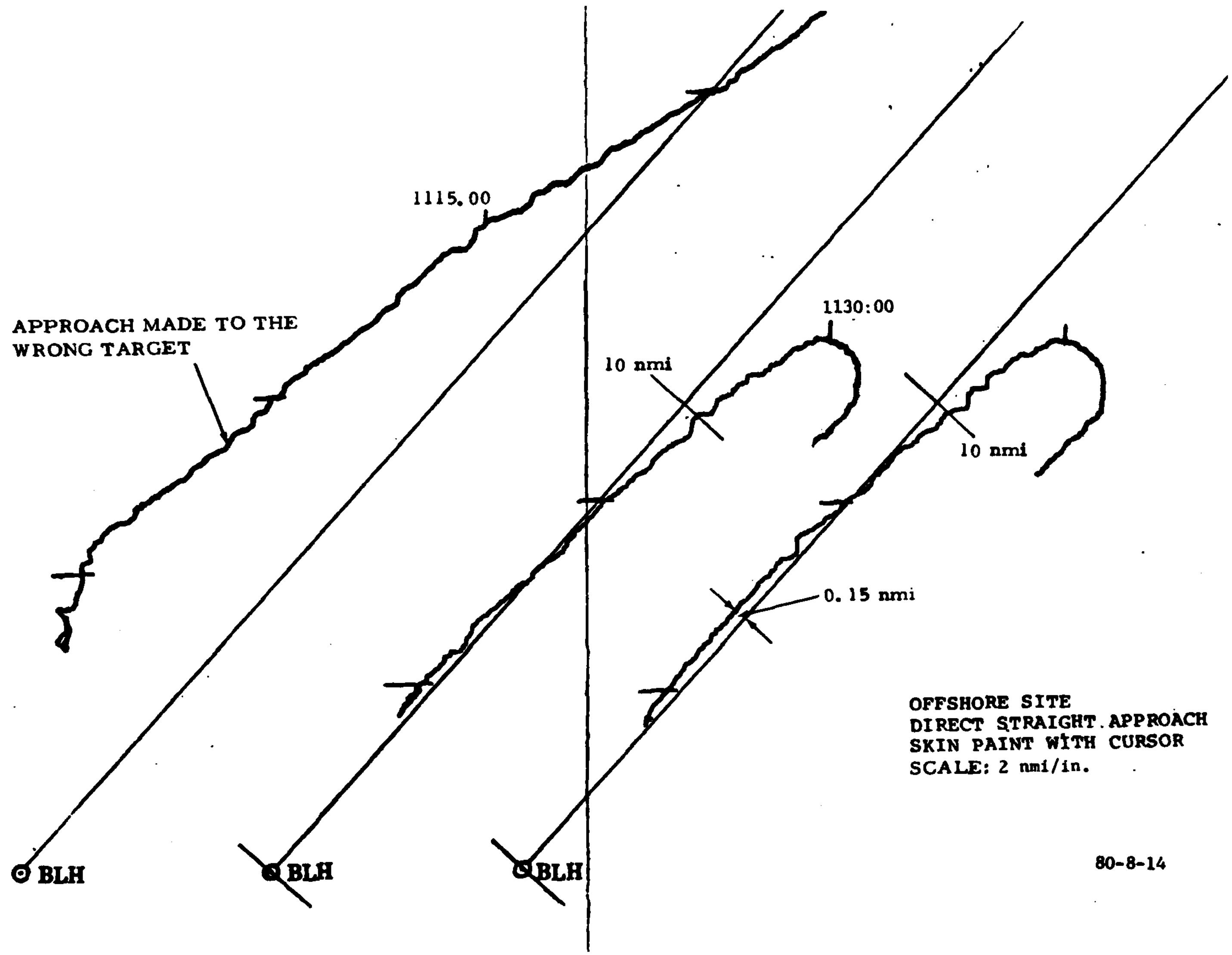


FIGURE 14. EAIR PLOTS OF OFFSHORE APPROACHES (WITH CURSOR)

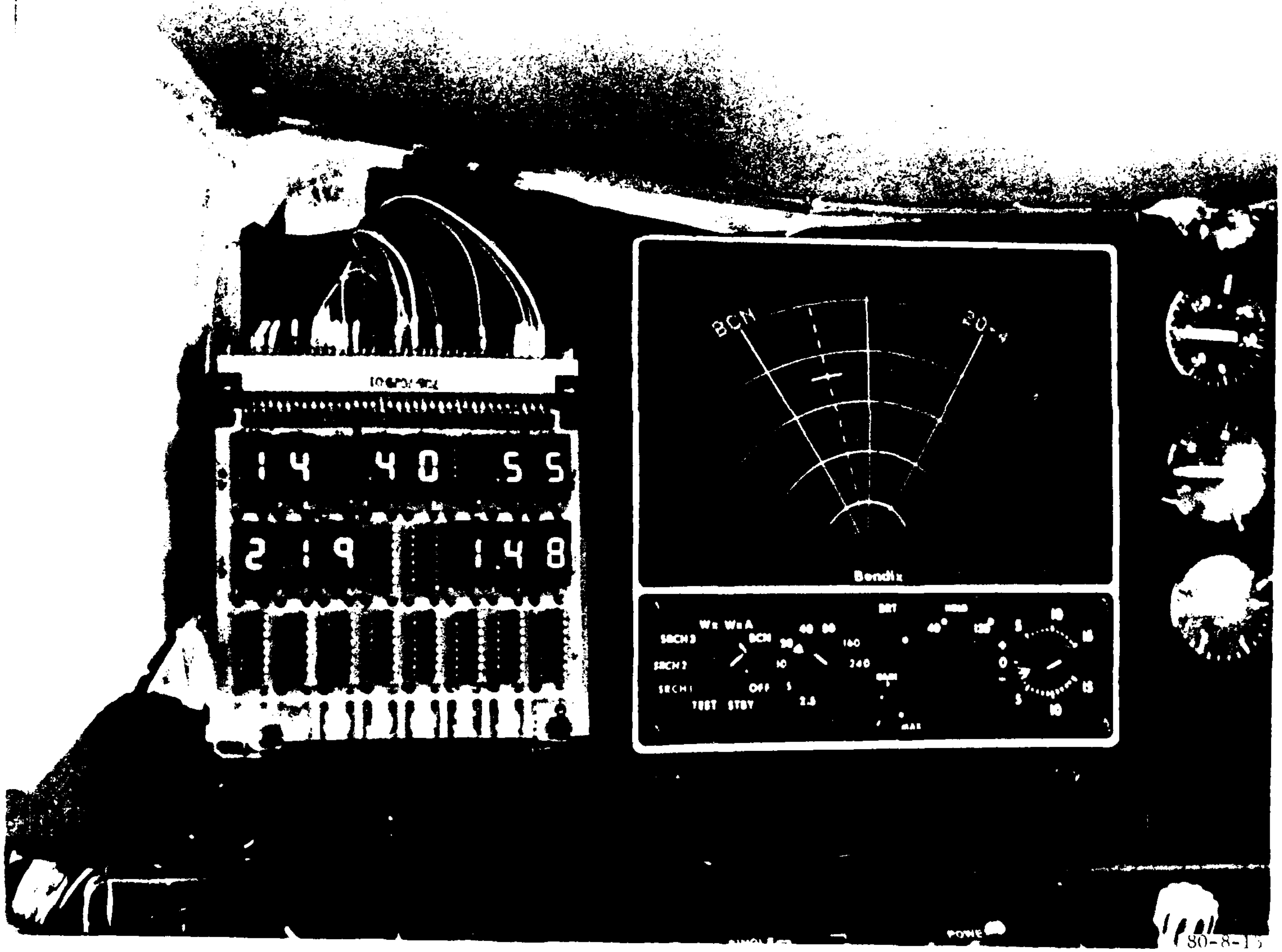


FIGURE 15. AIRPORT APPROACH, BEACON TARGET AT 15 nmi

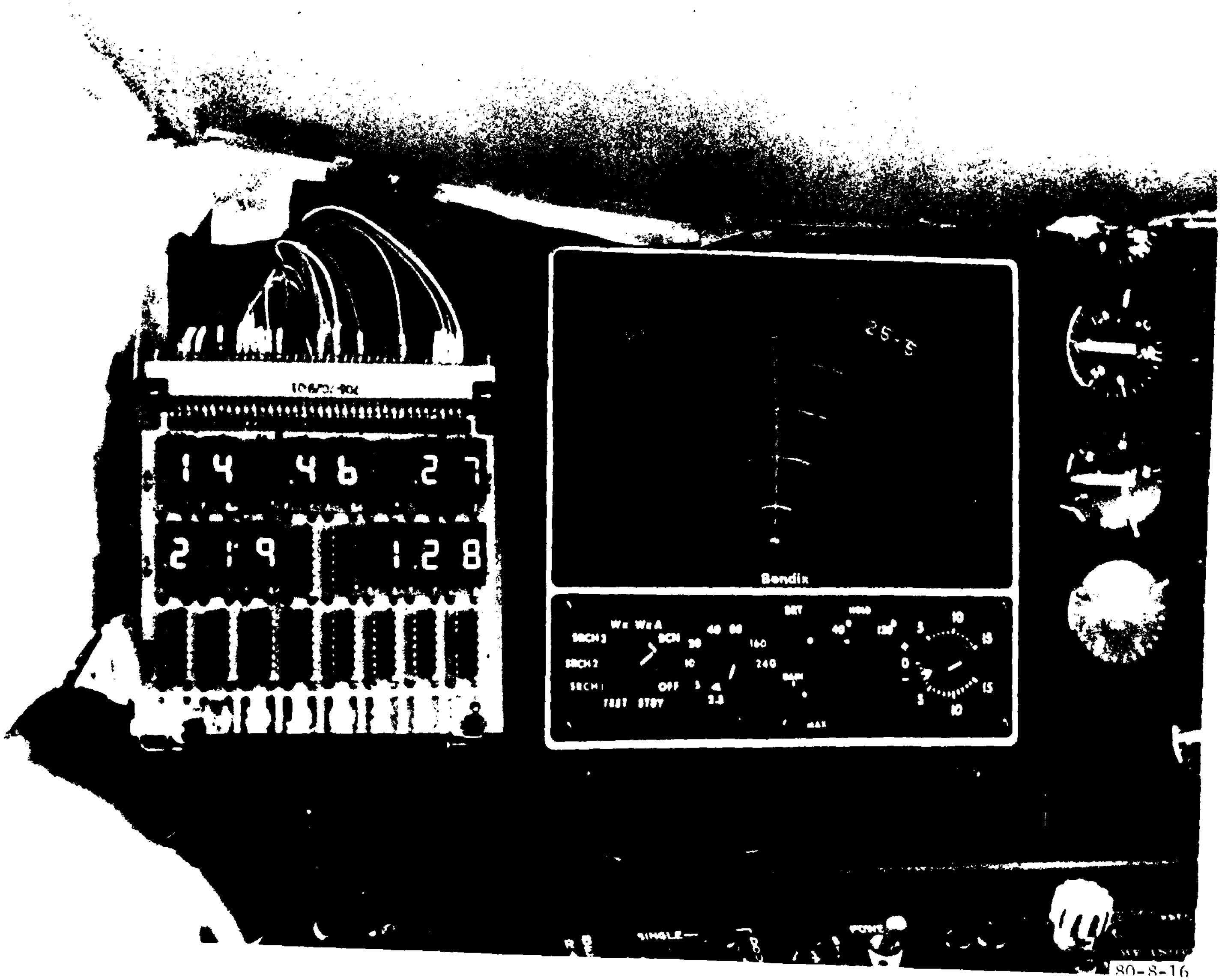


FIGURE 16. AIRPORT APPROACH, BEACON TARGET AT 2 1/4 nmi

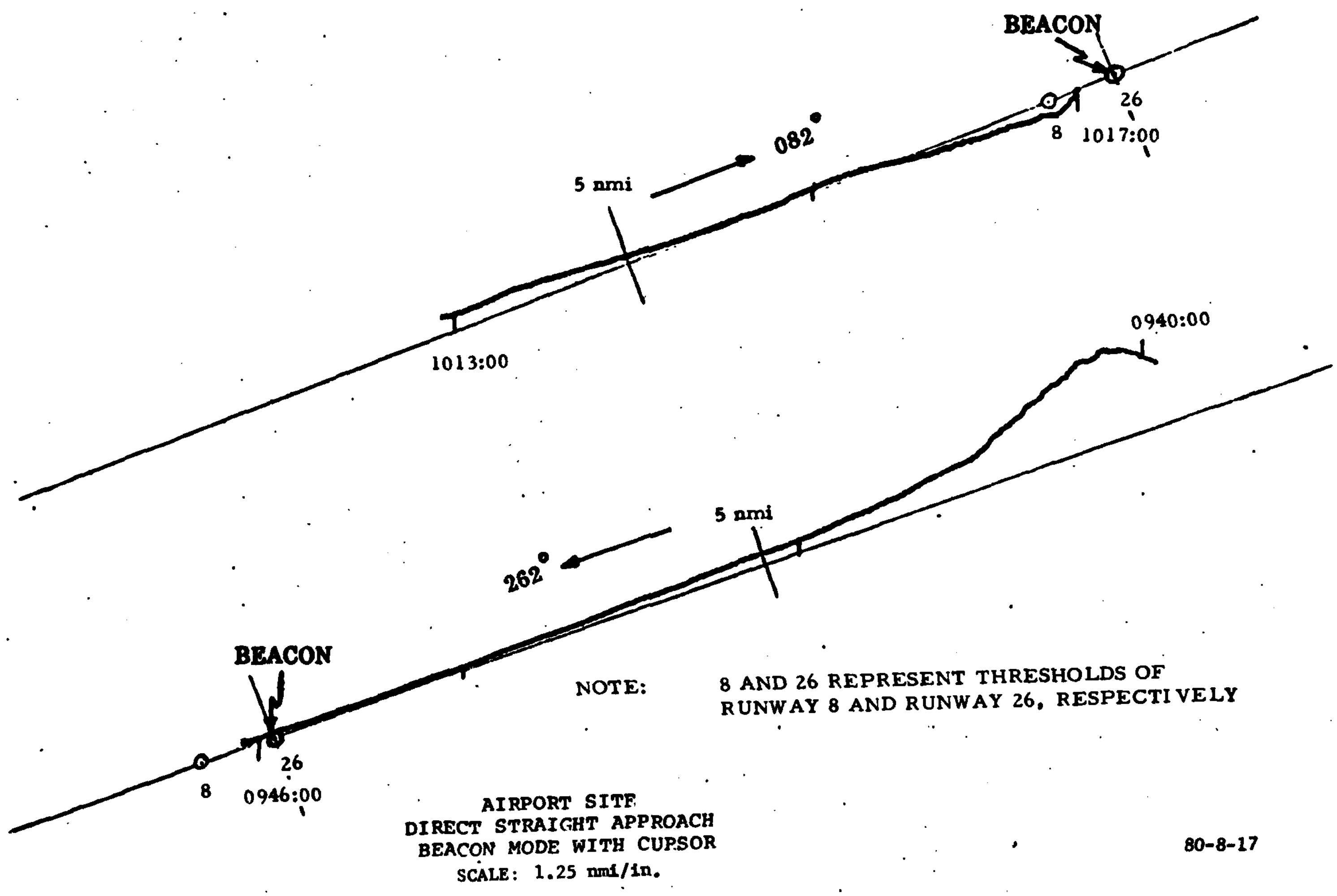


FIGURE 17. EAIR PLOTS OF AIRPORT APPROACHES (DIRECT STRAIGHT)

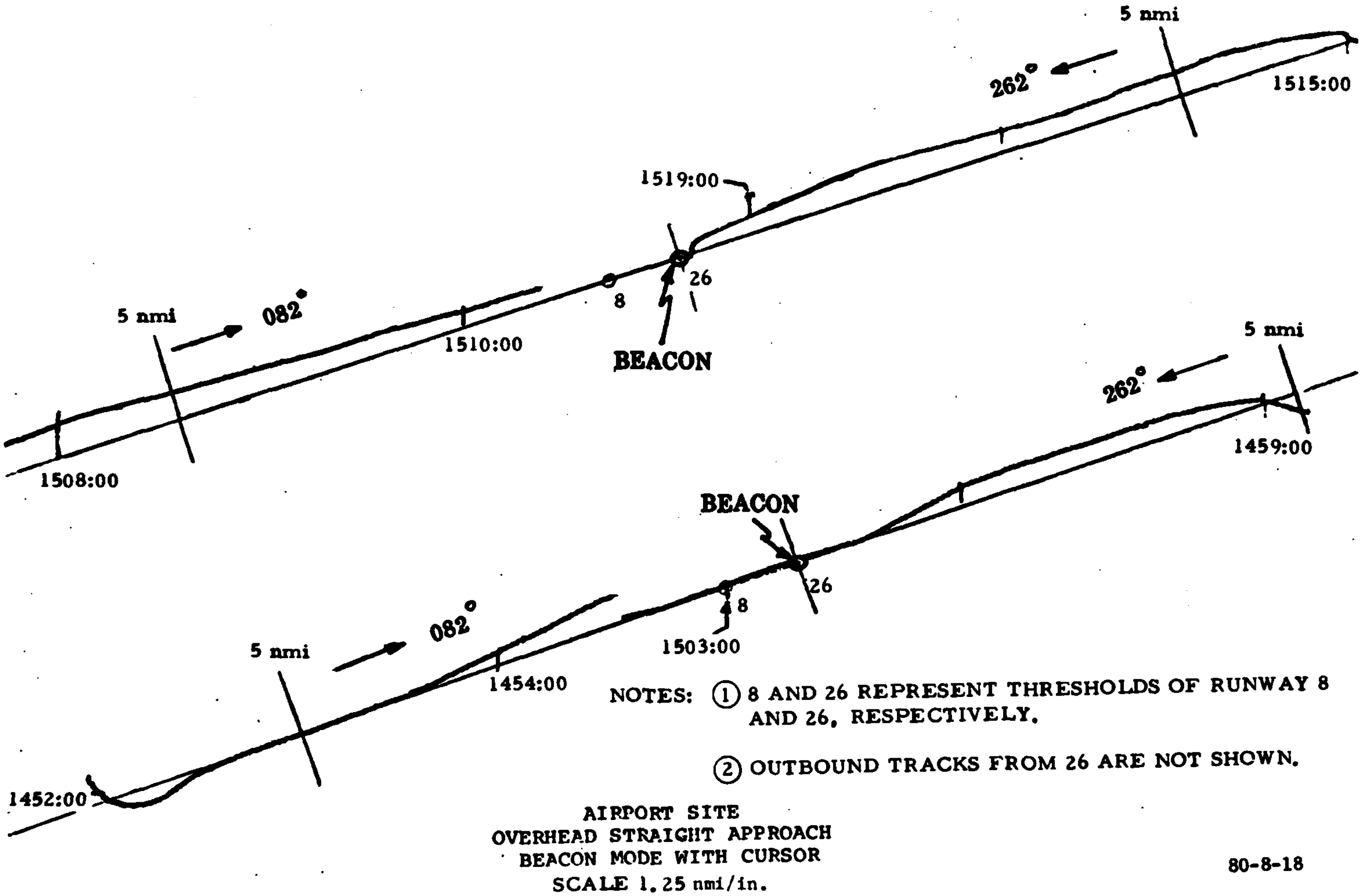


FIGURE 18. EAIR PLOTS OF AIRPORT APPROACHES (OVERHEAD STRAIGHT)

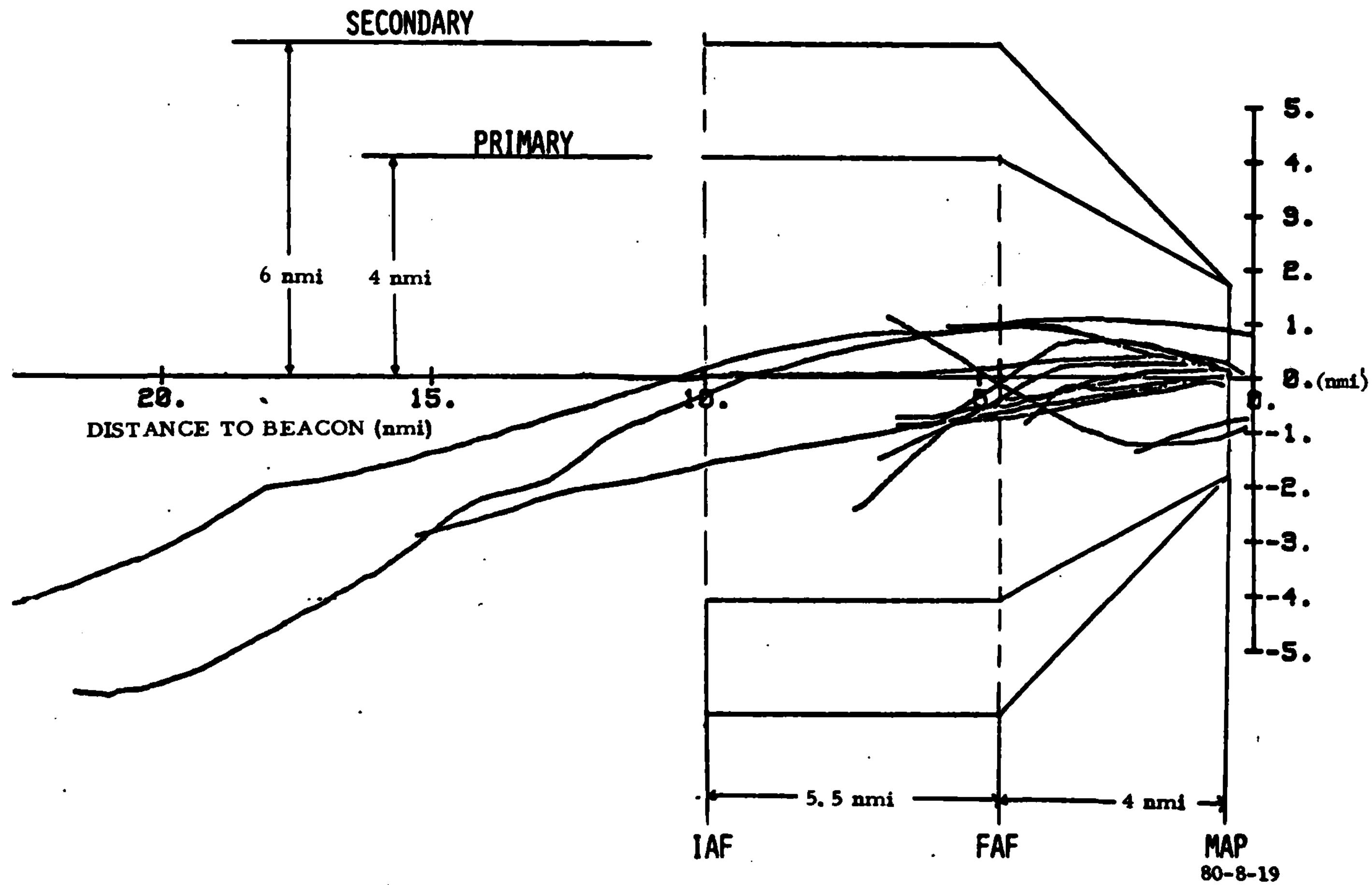


FIGURE 19. COMPOSITE PLOT OF AIRPORT APPROACHES (WITHOUT CURSOR) AS RELATED TO OBSTACLE CLEARANCE AIRSPACE

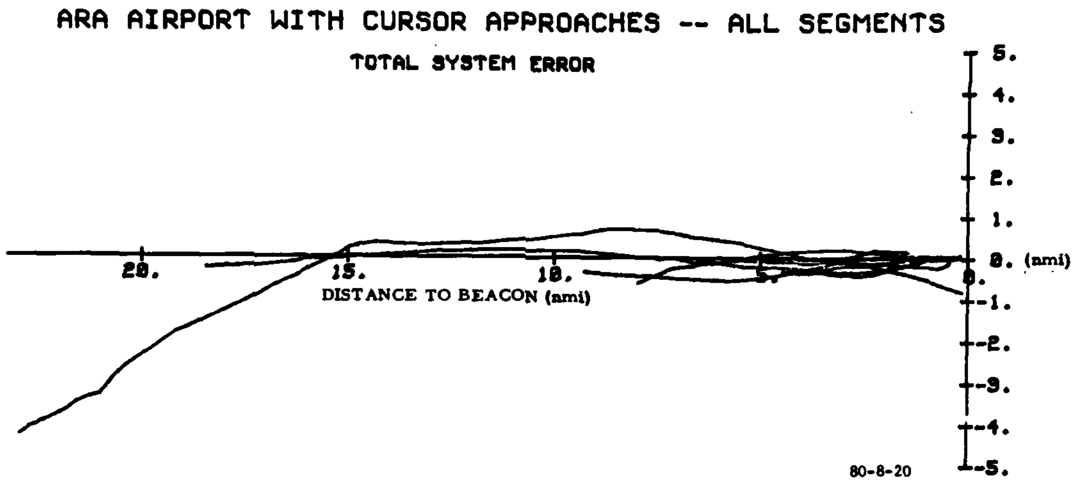


FIGURE 20. COMPOSITE PLOT OF AIRPORT APPROACHES (WITH CURSOR)

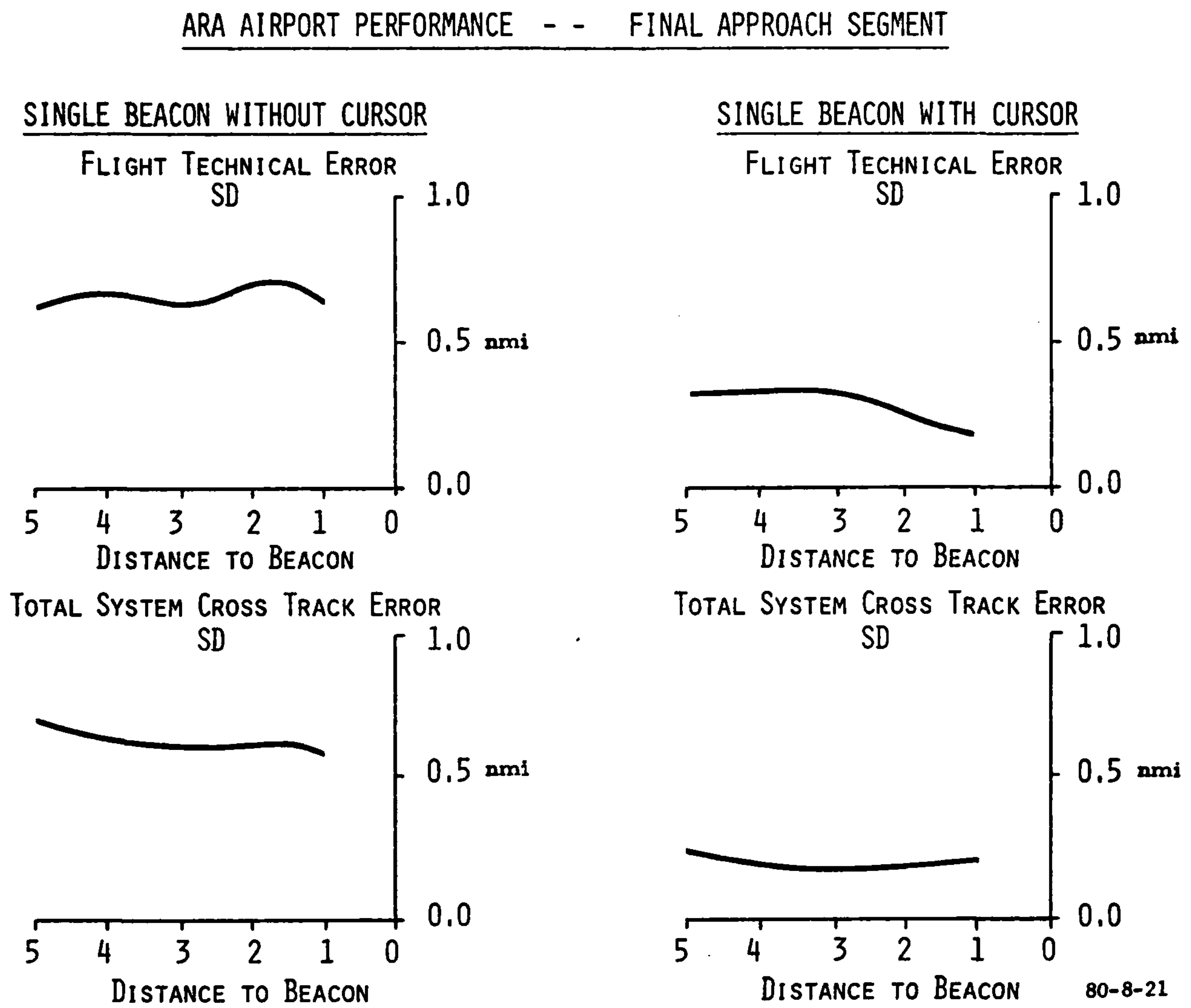


FIGURE 21. ARA AIRPORT PERFORMANCE, FINAL APPROACH SEGMENT

TABLE 1. FLIGHT TEST MATRIX

LOCATION	AIRPORT SITE												OFFSHORE SITE		NUMBER OF APPROACHES	COMMENTS
PROCEDURE	DIRECT STRAIGHT				OVERHEAD STRAIGHT				OVERHEAD OFFSET				DIRECT STRAIGHT			
SEGMENT LENGTH NM	25	5	25	5	25	5	25	5	25	5	25	5	25	10		
APPROACH COURSE TN	Rwy 26		Rwy 08		Rwy 26		Rwy 08		Rwy 26		Rwy 08		222°	222°		
FLIGHT #																
1													X	X X	3	Skin Paint Only
2													X	X X	3	Skin Paint Only
3													X	X X	3	Skin Paint Only
4													X	X X	3	Skin Paint With Cursor
5													X	X X	3	Skin Paint With Cursor
6													X	X X	3	Skin Paint With Cursor
7	X	X	X	X											4	Beacon Mode With Cursor
8					X	X	X	X							4	Beacon Mode With Cursor
9									X	X	X	X			4	Beacon Mode With Cursor
10							X	X			X				3	Intentional Offset Beacon Mode With Cursor
TOTAL	1	1	1	1	1	1	2	2	1	1	2	1	6	12	33	

TABLE 2. SINGLE BEACON AIRPORT APPROACH STATISTICAL SUMMARY

WITHOUT CURSOR	$\bar{x}$	σ	N	WITH CURSOR	$\bar{x}$	σ	N
FTE				**FTE**			
LONG	.8908	1.9144	263	LONG	.4534	1.1991	261
SHORT	.3927	.7203	294	SHORT	.0398	.3204	192
TOTAL	.6279	1.4361	557	TOTAL	.2781	.9552	453
TSCT				**TSCT**			
LONG	.9076	1.8025	263	LONG	.2697	.9415	261
SHORT	.2727	.6402	294	SHORT	.0437	.1649	192
TOTAL	.5725	1.3593	557	TOTAL	.1739	.7307	453