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**PRELIMINARY ASSESSMENT OF COAST GUARD
SURFACE VESSEL RADAR DETECTION PERFORMANCE**

S. R. Osmer and N. C. Edwards, Jr.
U. S. Coast Guard Research and Development Center
Avery Point, Groton, CT 06340

and

G. L. Hover and T. J. Mazour
Analysis and Technology, Inc.
P. O. Box 220, North Stonington, CT 06359

U.S. Coast Guard Research and Development Center
Avery Point Groton, Connecticut 06340



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K. D. URFER, CAPT, USCG
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U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340

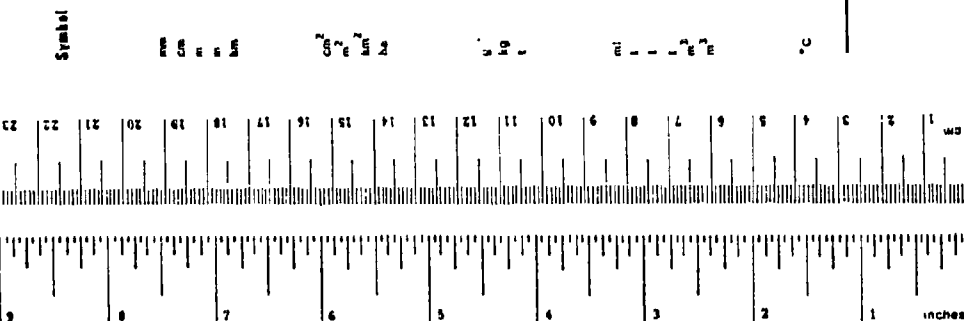
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16. Abstract Surface Vessel Radar (SVR) detection data have been collected in conjunction with two visual detection experiments conducted in 1980 and 1981 by the U.S.C.G. R&D Center. These are part of a series of experiments designed to improve search planning guidance contained in the <u>National Search and Rescue Manual</u> . 82-foot Coast Guard cutters equipped with the Raytheon AN/SPS-64(V) radar and 41-foot utility boats equipped with the Raytheon AN/SPS-66 radar conducted detection runs with 4- and 7-man life rafts and 15- to 18-foot fiberglass boats. Targets were equipped with varying amounts of reflective material. The AN/SPS-64(V) was found to achieve significantly longer detection ranges than the AN/SPS-66 with all target types. Metal posts with or without radar reflectors improved target detection ranges. Cumulative Detection Probability (CDP) versus range curves are presented for representative radar/target type combinations. Results are based upon very limited data; additional data will be collected during the fall of 1981.		13. Type of Report and Period Covered Interim Report April 1980 - August 1981
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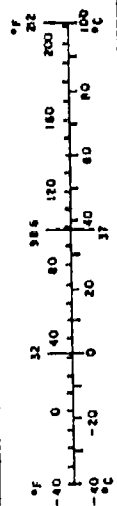
Approximate Conversions to Metric Measures

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 Spec. Publ. 280, Units of Weight and Measures, Part 2.25, SI Listing No. C13.10-280.



Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
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	ac
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	st
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
m ³	cubic meters	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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Chapter 1

BACKGROUND

1.1 SCOPE

This report presents preliminary results of Coast Guard Surface Vessel Radar (SVR) performance tests conducted in conjunction with visual (Reference 1) and side-looking airborne radar (SLAR) (Reference 2) detection experiments during the spring of 1980 and the winter of 1981. Targets included 15- to 19-foot fiberglass boats with varying amounts of reflective equipment and 4- to 7-man life rafts with and without canopy, mast, and/or radar reflector.

The performance of the AN/SPS-66 (installed on 41-foot UTBs) and the AN/SPS-64(V) (installed on 82-foot WPBs and larger cutters) in detecting these small search and rescue (SAR) targets is being evaluated as part of the project, Probability of Detection (POD) in SAR, by the U.S. Coast Guard Research and Development (R&D) Center. The ultimate goal of these SVR performance tests is to provide search planners with a quantitative detection model which can be used to predict POD for actual search missions.

Results presented in this report are based upon very limited data, and at this time should not be used to represent operational performance of Coast Guard SVR in the SAR mission. This report is an interim summary of test results to date. Further tests are planned for fall 1981; results will be published in spring 1982.

1.2 AN/SPS-64(V) AND AN/SPS-66 SYSTEM DESCRIPTIONS

The Raytheon AN/SPS-64(V) (Reference 3) is the surface search/navigation radar installed (or planned for installation) on Coast Guard cutters of 82-foot WPB class and larger. The AN/SPS-64(V) tested is X-band, operating at a frequency of 9420 (± 7) MHz with peak power output of 20 kW and a pulse-repetition frequency (PRF) of 900 to 3600 pps depending upon range scale selected. Beamwidth is 1.2 degrees for the 6-foot horizontally polarized antenna. The

antenna rotates at 33 RPM. Range scales available are .25, .5, .75, 1.5, 3, 3/power boost, 6, 12, 24, 48, and 64 nautical miles. Resolution varies with range scale selected and PRF, with an optimum of 20 yards on the .25, .5, and .75 range scales at 3600 pps. The AN/SPS-64(V) comes in several configurations. Data for this report were gathered using the Raytheon model RM 1220/6XR with a 12-inch plan position indicator (PPI) display. This model is installed on the 82-foot WPB class cutter.

The Raytheon AN/SPS-66 (Reference 4) is installed on the Coast Guard 41-foot UTB class. A watertight model, AN/SPS-66A, is planned for installation on the Coast Guard 44-foot MLB class boats. The AN/SPS-66 is X-band, operating at a frequency of 9375 (± 30) MHz with peak power output of 7 KW and a PRF of 3000 to 1500 pps depending upon range scale selected. Beamwidth is 3.5 degrees for the 2.5-foot horizontally polarized antenna. The antenna rotates at 30 RPM. Range scales available are .5, 1.5, 3, 6, 12, and 32 nautical miles, with power boost available on the .5, 1.5, and 3 nm range scales. Resolution varies with range scale selected and PRF, with an optimum of 25 yards on the .5, 1.5, and 3 nm ranges scales at 3000 pps. The AN/SPS-66 configuration tested was Raytheon model 3100 with a 7-inch PPI display.

1.3 DESCRIPTION OF THE EXPERIMENTS

The data for this report were collected during two experiments conducted during the spring of 1980 in Block Island Sound off the Connecticut/Rhode Island/New York coast and during the winter of 1981 off the coast of Panama City, Florida. Detailed descriptions of these detection experiments and the exercise areas can be found in References 1, 2, and 5.

1.3.1 Environmental Conditions

Environmental conditions were good to moderate during the two experiments. The range of environmental parameters of interest encountered during the SVR tests is given in Table 1-1.

Table 1-1. Range of Environmental Parameters Encountered

Parameter of Interest	Minimum	Maximum
Wind Speed (kt)	0.0	12.0
Swell Height (ft)	0.0	2.0
Visibility (nm)	1.0	15.0
Precipitation	none	fog/rain
Relative Humidity (%)	57	100

1.3.2 Targets

A variety of small boat and life raft targets were utilized during the experiments. Three types of radar reflective devices were installed on selected targets to determine what, if any, improvement in detectability resulted from their use. Since installation of a radar reflector on the small boats or rafts usually required use of a 1-3/4" x 6' metal post, similar targets were equipped with a metal post alone as a control. Some of the small fiberglass boats were equipped with an outboard or inboard/outboard engine. Table 1-2 summarizes the number of detection opportunities obtained for each target/equipment combination during the two SVR detection experiments.

1.3.3 Experiment Design and Conduct

Design

The two experiments described in this report were designed as system performance tests so that an upper bound on the detection capability of the AN/SPS-64 and -66 radars could be determined. Data collection was performed in a manner similar to that described for detection runs in Reference 6, except that radar operators were semi-alerted; that is, they had some knowledge of where and when to expect radar contacts to occur. The objective of these detection runs was to collect data for developing cumulative detection probability (CDP) versus range curves for each radar/target type combination

Table 1-2. Summary of Target Detection Opportunities

Small Fiberglass Boats			Life Rafts		
Target Description	No. of Detection Opportunities		Target Description	No. of Detection Opportunities	
	SPS-66	SPS-64(V)		SPS-66	SPS-64(V)
15- to 16-foot outboard without reflective equipment	15	14	7-man non-canopied life raft without reflective equipment	16	13
15- to 16-foot outboard with steel post (1 3/4" x 5')	5	3	7-man non-canopied life raft with steel post	6	3
15- to 16-foot outboard with steel post and Echomaster corner radar reflector	5	3	7-man non-canopied life raft with steel post and Echomaster corner radar reflector	7	3
16-foot outboard or 18-foot inboard/outboard with engine.	6	6	7-man non-canopied life raft with steel post and Morin gold screen radar reflector	7	3
			4-man canopied life raft without reflective equipment	10	7
			4-man canopied life raft with Mobay radar-reflective cloth canopy.	7	3
TOTALS	31	26		53	32

tested. These CDP curves will be used with data collected in future experiments to develop lateral range curves as inputs to the Coast Guard's Computer Assisted Search Planning (CASP) model (Reference 7) and to provide operational guidance for the employment of SVR as a SAR sensor.

Conduct

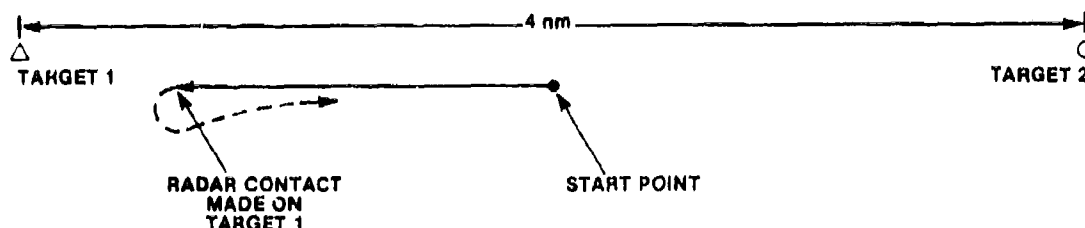
Prior to each day's experiment, a search and rescue exercise (SAREX) message was sent to participating units. The SAREX message assigned radar range scales and search patterns, specified search targets, and provided other information essential to the conduct of the experiment. The R&D Center UTB served as On-Scene Commander (OSC) in charge of setting and retrieving targets, communications, exercise control, and recording environmental parameters of interest.

The detection runs were conducted with an R&D Center observer aboard each search craft. The observer recorded time, relative bearing, and range for each radar contact reported by the radar operator along with other pertinent information including range scale utilized, visual confirmations, distractions, etc. Targets were approached from a range greater than the expected detection range and closed until detection occurred or the target passed close aboard the search unit. Target and search unit positions were monitored and reconstructed using a computer-automated Microwave Tracking System (MTS) described in Section 1.3.5.

1.3.4 Search Patterns

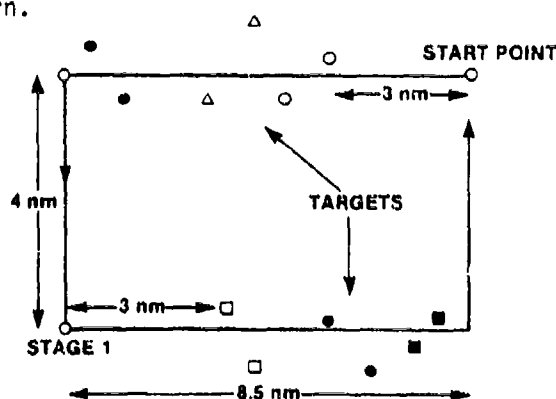
Two search patterns were employed during the SVR tests. Both were designed so that the search unit approached a target from a distance greater than the expected detection range and closed until detection occurred or a closest point of approach (CPA) of less than about 1/4 nm was reached. In this manner, data for CDP versus range curves could be generated for each target type. In practice, navigation errors sometimes resulted in start ranges of less than the expected detection range and CPAs larger than 1/4 nm; however, these problems were compensated for in the CDP calculations and reduced the radar operator's a priori knowledge of where and when to expect contacts to occur.

During the Spring 1980 Experiment, search units were instructed to make trackline runs back and forth between targets which were placed 4 nm apart. Range was closed until the first target was detected or CPA occurred (the search unit passed by the target without detecting). At that time, course was reversed and a similar approach was made on a second target (see sketch 1).



Sketch 1. Trackline Runs (Spring 1980 Experiment)

During the Winter 1981 Experiment in Panama City, Florida, a search pattern consisting of 2 parallel legs 8.5 nm long and 4 nm apart was assigned to the search units. Targets were placed near the assigned trackline beginning 3 nm from the start of each leg, as shown in sketch 2. This pattern provided a greater number of detection opportunities per search hour than the trackline runs did. Targets were placed far enough apart so that detection of one target would not interfere with the operator's ability to detect successive targets. The Naval Coastal Systems Center (NCSC) data collection platform (Stage I) was used as a reference point to assist search units in executing their assigned search pattern.



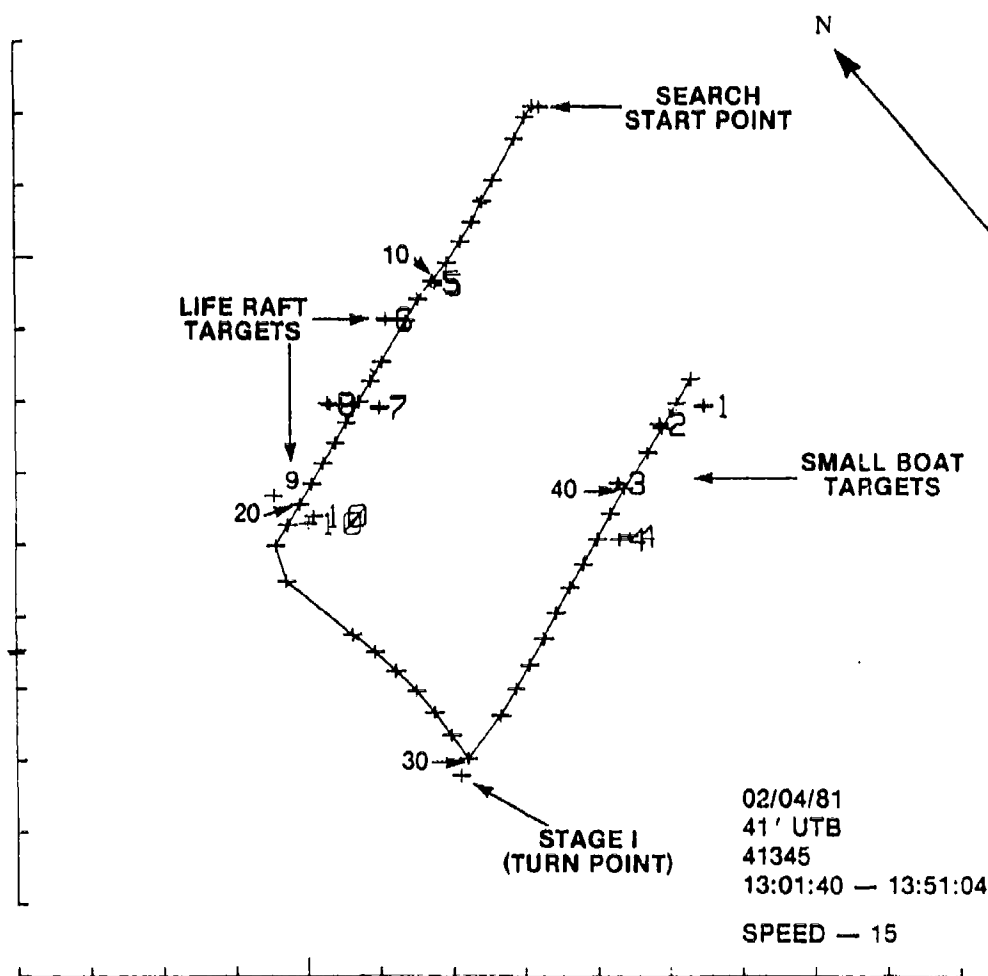
Sketch 2. Parallel Search Pattern (Winter 1981 Experiment)

1.3.5 Tracking and Reconstruction

Target locations and search unit positions were monitored using an automated Microwave Tracking System (MTS) consisting of a Motorola MiniRanger III mobile radar tracking system coupled with a Hewlett-Packard 9845B minicomputer and model 9872A plotter. This system was developed by the Coast Guard Research and Development Center for the POD in SAR Project to provide target position and search track reconstruction accurate to 0.1 nm. Its operation is described in detail in Reference 1. Detection and CPA ranges were determined for each target opportunity by referring to detection logs kept by the observer aboard each search unit and MTS position/time plots. When the range and relative bearing of a contact reported by the radar operator agreed with the MTS plot, a target detection was recorded. Actual detection ranges were measured on the MTS plot directly from the search unit's trackline position at time of contact to the target position. An example of an MTS position plot and time printout for a search conducted during the Winter 1981 Experiment is shown in Figure 1-1.

1.4 ANALYSIS APPROACH

The start ranges and detection or CPA (in the case of missed targets) ranges for all target opportunities were sorted by radar and target type into the categories shown in Table 1-2. Because of the very limited size of this data base, no distinction between radar range scale utilized could be made for this preliminary analysis. The data were input to a computer program which calculates and plots CDP as a function of range. This computer program constructs CDP versus range curves in accordance with procedures outlined in Reference 8, and the reader is referred to that document for details regarding CDP calculations. A simplified discussion of CDP calculations is given in Reference 6. Resultant CDP curves for representative radar/target type combinations are presented in Chapter 2. These CDP curves will be utilized along with blip/scan ratios (from planned future experiments) to develop lateral range curves for radar detection of small targets. A discussion of this technique is presented in Reference 6.



02/04/81

SEARCH BY 41' UTB - 41345

1 - 13:01:40	2 - 13:02:32	3 - 13:03:32	4 - 13:04:32
5 - 13:06:30	6 - 13:07:30	7 - 13:08:30	8 - 13:09:30
9 - 13:10:30	10 - 13:11:29	11 - 13:12:30	12 - 13:13:30
13 - 13:15:30	14 - 13:16:31	15 - 13:17:31	16 - 13:18:31
17 - 13:19:31	18 - 13:20:31	19 - 13:21:31	20 - 13:22:31
21 - 13:23:31	22 - 13:24:31	23 - 13:26:33	24 - 13:29:32
25 - 13:30:32	26 - 13:31:32	27 - 13:32:32	28 - 13:33:32
29 - 13:34:32	30 - 13:35:32	31 - 13:37:33	32 - 13:38:36
33 - 13:39:33	34 - 13:40:36	35 - 13:41:37	36 - 13:42:36
37 - 13:43:33	38 - 13:44:33	39 - 13:45:33	40 - 13:46:33
41 - 13:48:04	42 - 13:49:04	43 - 13:50:04	44 - 13:51:04

Figure 1-1. Example of MTS Plot

Mean detection ranges for each radar/target type combination were also calculated and are included in Chapter 2. A computer routine which performs two-way analysis of variance (Reference 9) was used to test for significant differences in mean detection range achieved by the two radar systems. The various target types were also compared in the analysis of variance to determine what effect, if any, reflective equipment had on detection range.

Chapter 2

RESULTS

2.1 DETECTION RANGES

As shown in Tables 2-1 and 2-2, a total of 84 detection opportunities for the AN/SPS-66 radar and 58 detection opportunities for the AN/SPS-64(V) radar were obtained for 10 distinct target types during the experiments. As the tables indicate, only a small amount of data exists for most of the radar/target type combinations.

A computer routine which performs two-way analysis of variance for unbalanced data (Reference 9) was utilized to identify significant differences in mean detection range among target types and between the two radar systems. Results of this analysis indicate the following:

Radar Type - Even with limited data, the AN/SPS-64(V) shows a clear superiority in detection range to the AN/SPS-66 under good conditions. Mean detection ranges for all of the 10 target types tested were greater for the AN/SPS-64(V) radar than for the AN/SPS-66. This difference was found to be significant at the .001 alpha level.

Reflective Equipment - No significant* difference in mean detection range was found between small boats or 7-man life rafts with a steel post alone and those with a steel post and Echomaster or Morin radar reflector. These target types, however, were all detected at significantly longer ranges than the boats and rafts without reflective equipment of any kind. This result suggests that the steel posts themselves were sufficient to improve target detectability, and the radar reflectors tested did not enhance detection performance any further. The Mobay radar reflective cloth did not increase detection ranges achieved with the 4-man canopied life rafts.

*The term "significant" in this discussion indicates that mean detection ranges for the target types being compared were shown to be different at the .05 alpha level.

Table 2-1. Summary of AN/SPS-66 Detection Data

TARGET TYPE	No. of Detections	Mean Detection Range (nm)	Minimum Detection Range (nm)	Maximum Detection Range (nm)	No. of Targets Missed	Mean CPA of Misses (nm)	Total Opportunities
15- to 16-foot fiberglass outboard without reflective equipment	7	0.9	0.1	2.4	8	0.9	15
15- to 16-foot fiberglass outboard with steel post	5	1.1	0.7	1.6	0	-	5
15- to 16-foot fiberglass outboard with steel post and Echomaster corner radar reflector	5	0.9	0.7	1.2	0	-	5
16-foot fiberglass outboard or 18-foot fiberglass inboard/outboard with engine	5	0.5	0.4	0.7	1	0.1	6
7-man non-canopied life raft without reflective equipment	9	0.5	0.3	0.7	7	0.5	16
7-man non-canopied life raft with steel post	4	1.1	0.6	1.5	2	0.8	6
7-man non-canopied life raft with steel post and Echomaster corner radar reflector	6	1.2	0.9	1.8	1	0.2	7
7-man non-canopied life raft with steel post and Morin gold-screen radar reflector	7	1.1	0.7	1.6	0	-	7
4-man canopied life raft without reflective equipment	8	1.0	0.5	1.9	2	0.3	10
4-man canopied life raft with Mobay radar-reflective cloth canopy.	7	0.7	0.4	1.3	0	-	7
OVERALL	63	0.9	0.1	2.4	21	0.6	84

Table 2-2. Summary of AN/SPS-64(V) Detection Data

TARGET TYPE	No. of Detections	Mean Detection Range (nm)	Minimum Detection Range (nm)	Maximum Detection Range (nm)	No. of Targets Missed	Mean CPA of Misses (nm)	Total Opportunities
15- to 16-foot fiberglass outboard without reflective equipment	12	1.3	0.7	2.5	2	0.7	14
15- to 16-foot fiberglass outboard with steel post	3	2.4	2.2	2.6	0	-	3
15- to 16-foot fiberglass outboard with steel post and Echomaster corner radar reflector	3	2.8	2.3	3.4	0	-	3
16-foot fiberglass outboard or 18-foot fiberglass inboard/outboard with engine	3	0.8	0.7	0.9	3	0.6	6
7-man non-canopied life raft without reflective equipment	8	1.7	1.0	3.8	5	0.6	13
7-man non-canopied life raft with steel post	2	2.0	1.9	2.1	1	0.3	3
7-man non-canopied life raft with steel post and Echomaster corner radar reflector	3	2.2	2.1	2.3	0	-	3
7-man non-canopied life raft with steel post and Morin gold-screen radar reflector	2	2.3	2.1	2.4	1	0.4	3
4-man canopied life raft without reflective equipment	4	1.7	1.1	2.3	3	1.1	7
4-man canopied life raft with Mobay radar-reflective cloth canopy.	1	1.1	-	-	2	0.1	3
OVERALL	41	1.7	0.7	3.8	17	0.6	58

Engines - Small fiberglass boats with an engine were detected at ranges no greater than those achieved for boats without engine or reflective equipment.

It is emphasized that the results presented above are based upon very limited data, and should be accepted with caution pending additional data collection.

2.2 CDP CURVES

Figures 2-1 through 2-3 are CDP curves for representative radar/target type combinations in the data base.

Figures 2-1 and 2-2 depict performance of the AN/SPS-64 and -66 radars in detecting fiberglass boats and 7-man life rafts without reflective equipment. Comparison of CDP curves for the two radars indicates that the AN/SPS-64(V) detects at longer ranges than the AN/SPS-66, with the result that CDP is consistently higher at all ranges. In an actual search, this performance difference would translate to the AN/SPS-64(V) being capable of searching an area more quickly (with equal effectiveness) than the AN/SPS-66 by using wider track spacing.

Figure 2-3 compares CDP curves for the AN/SPS-66 radar detecting 7-man life rafts with steel post and radar reflector and 7-man life rafts without reflective equipment. As the figure indicates, rafts with steel post and reflector had a much higher CDP at all ranges than rafts without reflective equipment. In addition, at a range of 0.2 nm CDP builds to .93 for the reflector-equipped rafts compared to .73 for rafts without reflective equipment, indicating the reflector-equipped rafts are more likely to be detected even when very close CPAs are involved. These results indicate that some type of metal reflective equipment is likely to substantially improve the chances of a life raft being detected by radar. As was mentioned in Section 2.1, the data do not presently indicate that any particular form of metal reflective equipment tested was superior to the others.

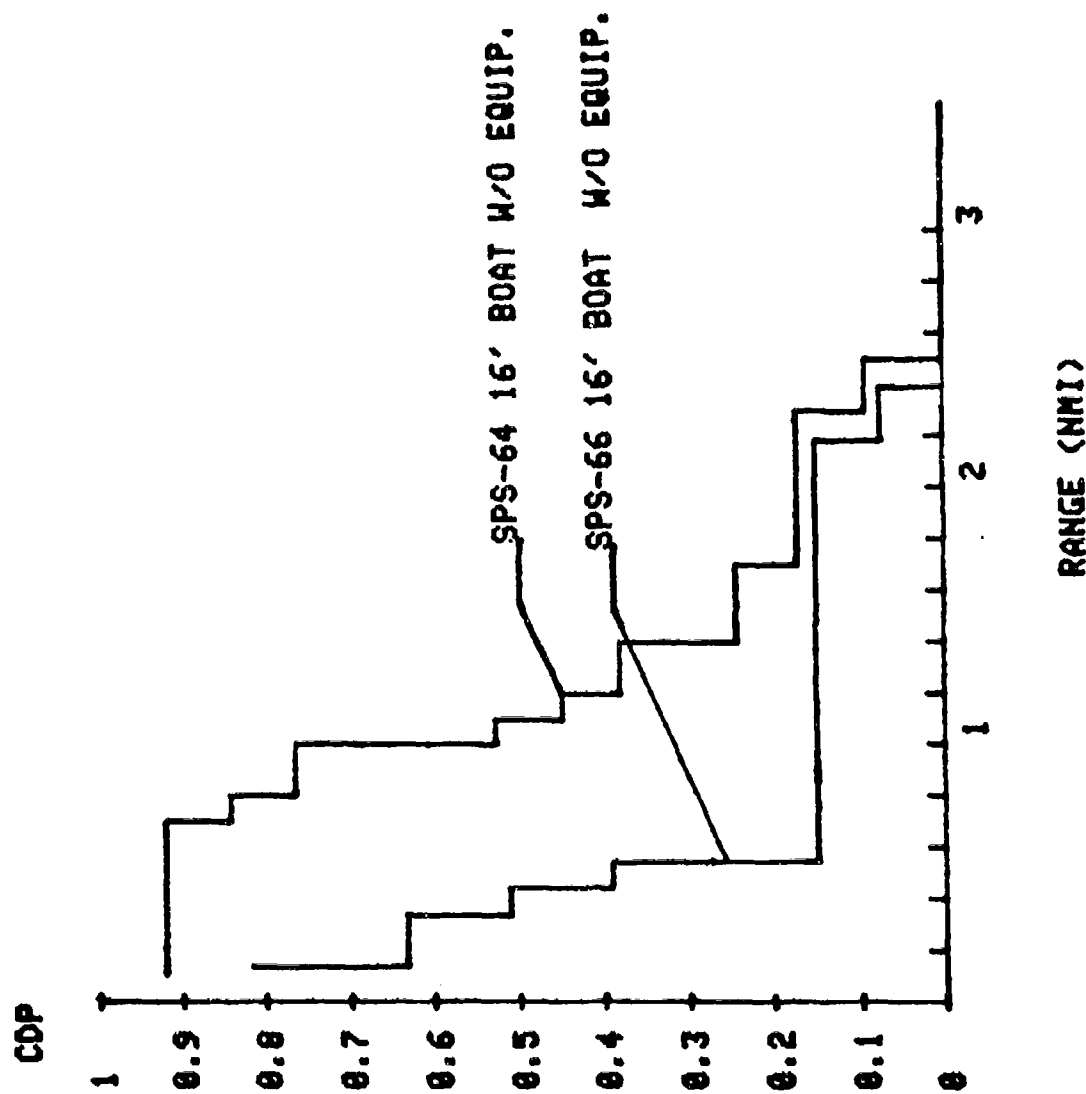


Figure 2-1. Comparison of CDP For AN/SPS-64(V) and AN/SPS-66 Radars (16-Foot Boat Targets Without Reflective Equipment)

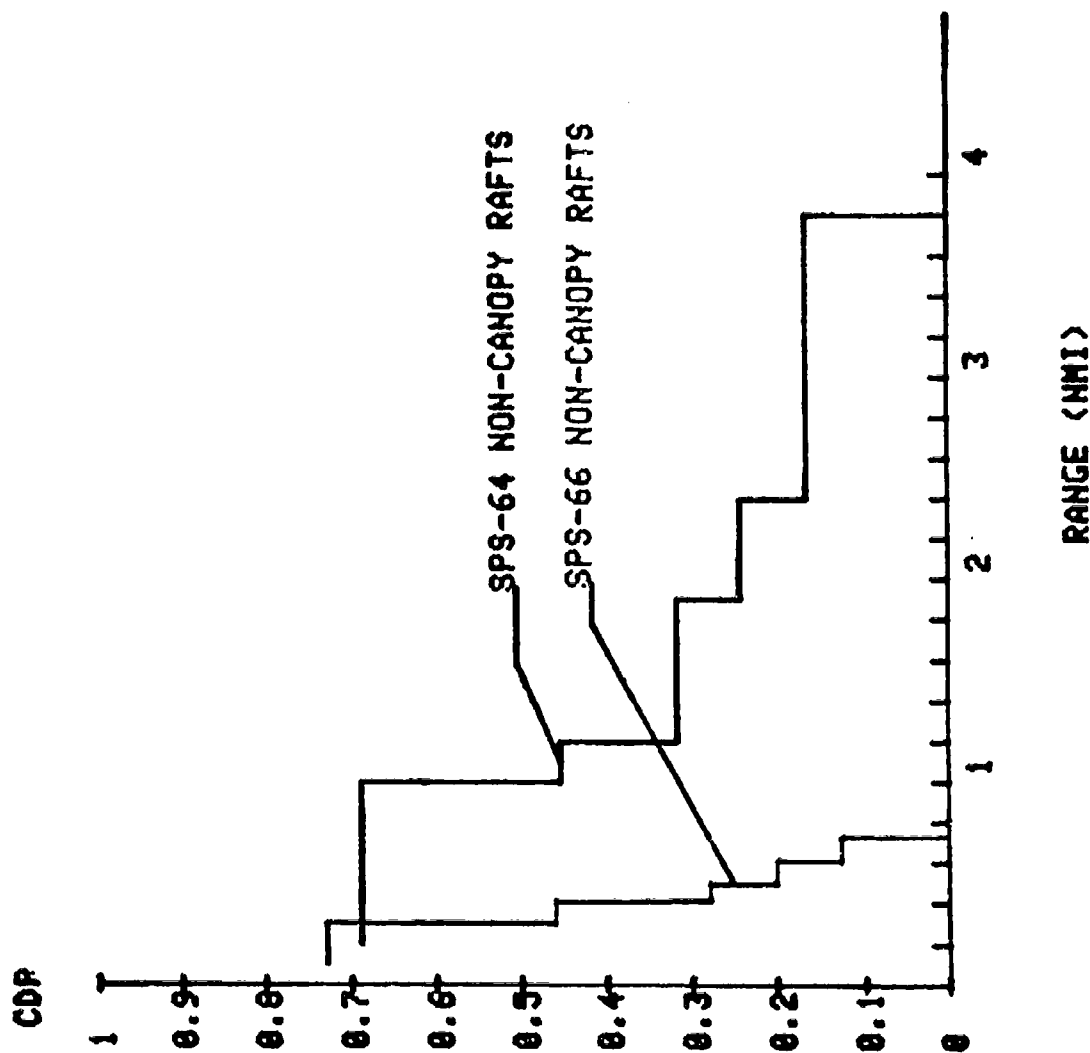


Figure 2-2. Comparison of CDP For AN/SPS-64(V) and AN/SPS-66 Radars (7-Man Life Raft Targets Without Reflective Equipment)

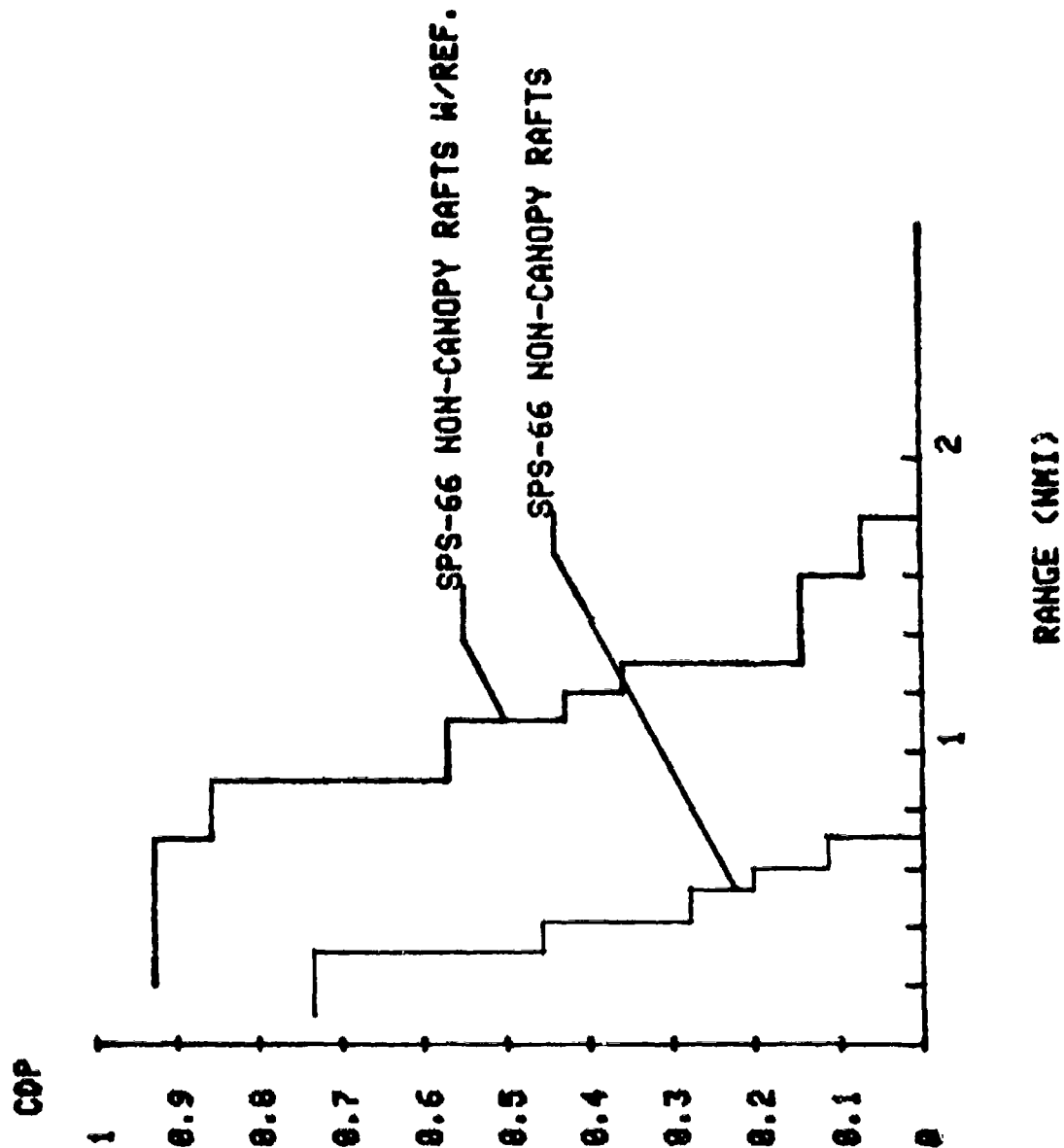


Figure 2-3. Comparison of CDP For Life Rafts With and Without Radar Reflector (AN/SPS-66 Radar)

2.3 COMPARISON TO VISUAL SEARCH

As a means of putting this preliminary assessment of SVR search capability in perspective, a comparison to visual search performance can be made. During visual searches for small boats and life rafts which were conducted as part of the POD in SAR Project, about 50% of visual detections were made at ranges less than 2 nm, with 95% of the detections occurring inside of 4 nm. By comparison, 59% of AN/SPS-66 detections occurred inside of 1 nm, and 97% occurred inside of 2 nm. With the AN/SP6-64(V), 49% of the detections occurred inside of 1.5 nm, and 95% occurred inside of 3 nm. Also worthy of note is the fact that visual scanners aboard search craft during the SVR tests almost always sighted targets before radar contact was made, and most of the targets missed by the radars were sighted visually.

The statistics presented above indicate that, with small targets, SVR is most likely to have potential as an important SAR sensor in night and low visibility conditions. In moderate* or better weather conditions during daylight hours, dedicating a crewperson who would otherwise be used as a visual scanner to the radar display does not appear to be warranted. This tradeoff is an especially important one in the case of 41- and 44-foot boats with only 3 crewpersons.

The question of whether SVR can outperform visual lookouts in rougher sea conditions than those represented in the present data remains unanswered pending future data collection. Further investigation into the improvement in detectability achievable through the use of radar reflective devices should also be conducted, since detection performance of the AN/SPS-64(V) with reflector-equipped targets did approach that achieved by visual lookouts.

*Moderate conditions are defined as visibility ≥ 5 nm, wind speed ≤ 15 kt, swell height ≤ 2 ft.

Chapter 3

PLANNED FUTURE WORK

3.1 CDP DETECTION DATA

Additional CDP detection runs similar to those conducted in Panama City, Florida are planned for the Fall 1981 Electronic Detection Experiment in Block Island Sound. Targets similar to those already tested as well as 12- to 16-foot aluminum boats will be utilized. The objective of this additional data collection will be to produce reliable CDP curves for all radar/target type combinations tested. It will also be desirable to collect CDP data under more severe weather conditions (i.e., wind speed >10kt, swell height ≥3 ft, precipitation, fog) to determine how these conditions affect the performance of the two radar systems.

3.2 BLIP/SCAN DATA

Tracking runs (Reference 6) will also be conducted during the Fall 1981 Experiment with all radar/target type combinations to collect blip/scan ratio data. The blip/scan ratio is an estimate of the instantaneous probability that radar will detect a target at a given range. Knowing the blip/scan ratio and CDP for a given radar/target type combination at various ranges facilitates the development of a lateral range curve (Reference 6). The lateral range curve is used by search planners to select track spacing and estimate overall POD for a search. Further discussion of search performance measures and search planning can be found in References 1, 2, 5, and 10.

The blip/scan ratio can also be used to estimate the range ($R_{.50}$) at which a radar has a 50% probability of detecting a given target. This range can be used along with other radar and environmental parameters in the radar range equation to calculate the target's radar cross-section (σ). Once a reliable radar cross-section has been calculated, radar detection performance estimates can be extrapolated (with caution) to environmental conditions not present in the experiment data base. Discussion of the radar range equation and specific parameter values for the AN/SPS-64(V) and AN/SPS-66 radars can be

found in Reference 11. Additional discussion of the radar range equation and calculation of target cross-section can be found in References 12 and 13.

REFERENCES

1. Edwards, N. C.; Osmer, S. R.; Mazour, T. J.; and Hover, G. L. Analysis of Visual Detection Performance for 16-Foot Boat and Life Raft Targets. Report No. CG-D-24-80. USCG Research and Development Center and Analysis & Technology, Inc., February 1980.
2. Osmer, S. R.; Edwards, N. C. Jr.; Hover, G. L.; and Mazour, T. J. Evaluation of Two AN/APS-94 Side-Looking Airborne Radar Systems in the Detection of Search and Rescue Targets. USCG Research and Development Center and Analysis & Technology, Inc., August 1981.
3. Raytheon Marine Co. "Mariner's Pathfinder Radar Instruction Manual for AN/SPS-64", U.S. Coast Guard.
4. Raytheon Marine Co. "Technical Manual for Radar Set AN/SPS-66 and AN/SPS-66A", U.S. Coast Guard.
5. Edwards, N. C.; Osmer, S. R.; Mazour, T. J.; and Hover, G. L. Factors Affecting Coast Guard SAR Unit Visual Detection Performance. USCG Research and Development Center and Analysis & Technology, Inc., August 1981.
6. Operations Analysis Study Group, U.S. Naval Academy, Naval Operations Analysis. Naval Institute Press, Annapolis, MD, 1977.
7. Computerized Search and Rescue Handbook. U.S. Coast Guard, 1 January 1974.
8. Commander, Submarine Development Squadron Two, Submarine Analysis Notebook (Revised). U.S. Naval Submarine Base, Groton, CT. September 1973. (CONFIDENTIAL)
9. PLOT 50 Statistics, Volume 2. Tektronix, Inc., 1976.

10. U.S. Coast Guard, National Search and Rescue Manual. CG-308, Superintendent of Documents, Washington, D.C.: Government Printing Office, July 1973, with amendments 1-2.
11. J. D. Hersey, "Predicting Radar Performance in Weather", Coast Guard Engineer's Digest. CG-133, U.S. Dept. of Transportation, Washington, D.C., Fall 1979.
12. L. V. Blake, "A Guide to Basic Pulse Radar Maximum Range Calculations", NTIS #AD 701 321, 1969.
13. Merril I. Skolnik, Introduction to Radar Systems. McGraw-Hill, N.Y., 1962.

Appendix A
METRIC CONVERSION FACTORS

1. Feet to Meters

1 foot = 0.3048 meters

Thus:

3- to 4-foot swells $\approx$ 1-meter swells,
a 16-foot boat $\approx$ a 5-meter boat, and
an altitude of 500 feet $\approx$ a 150-meter altitude.

2. Nautical Miles to Kilometers

1 nautical mile (nm) = 1.852 kilometers (km)

Thus:

10 nm visibility $\approx$ 18.5 km visibility, and
a 2-nm range $\approx$ a 3.7-km range.

3. Knots to Meters per Second and Kilometers per Hour

1 knot = 0.5144 meters per second

1 knot = 1.852 kilometers per hour

Thus:

a 10-knot wind speed $\approx$ a wind speed of 5 meters per second, and
a 10-knot search speed $\approx$ a search speed of 18 kilometers per hour.