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AN/APS-137 FORWARD LOOKING AIRBORNE RADAR (FLAR) EVALUATION SPRING 1992 EXPERIMENT INTERIM REPORT

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NOTICE

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15. Supplementary Notes

This report is the eighth in a series that will document the Improvement of Search and Rescue Capabilities (ISARC) Project at the U.S.C.G. R&D Center and thirty-fourth in a series of R&D Center reports dealing with Search and Rescue (SAR).

16. Abstract

During April 1992, the U.S. Coast Guard R&D Center conducted an experiment to determine the sweep width for the AN/APS-137 Forward Looking Airborne Radar (FLAR) when searching for 4-, 6-, and 10-person life rafts. A total of 507 target detection opportunities were generated for life-raft targets.

The experiment was conducted in the coastal waters off the west coast of Florida from Wacussa Bay to Gasparilla Island. Radar searches to collect data used unalerted sensor operators and standard search patterns. Aircraft and target positions were recorded using a Differential Global Positioning System (DGPS). Target detections were recorded by observers on board the aircraft, and environmental conditions were recorded by observers on the workboats. In addition, two MINIMET™ environmental buoys recorded the sea and wind conditions in the search area. Environmental conditions represented in the data set included 1.6 to 3.6 foot significant wave heights and 2.9 to 13.0 knot winds.

Analysis of the data confirmed sweep width to be largely determined by lateral range and significant wave height (Hs). Search altitude was not a significant variable for these data. The AN/APS-137 FLAR detection performance decreased with even a small increase in Hs. For Hs values up to 3.6 feet, the AN/APS-137 FLAR performed notably better than the AN/APS-127 FLAR with the largest differences occuring for higher Hs conditions. Recommended sweep width values and search guidance for the AN/APS-137 FLAR are presented. Raw data are also included.

Recommendations for sweep width values for life-rafts should be incorporated into the Coast Guard Addendum to the National Search and Rescue Manual.

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UNCLASSIFIED	UNCLASSIFIED		

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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
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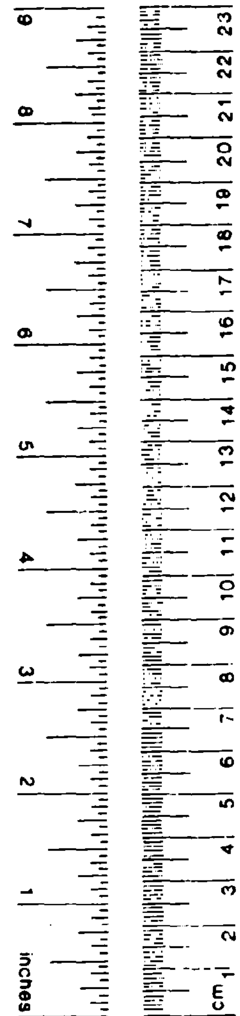
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

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		LENGTH		
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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	0.125	cups	c
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)		
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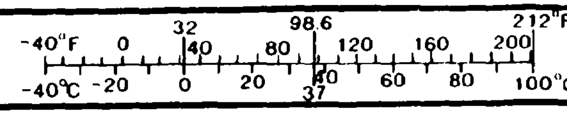

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EXECUTIVE SUMMARY

INTRODUCTION

1. Background

This report provides an analysis of an experiment that was conducted to evaluate the AN/APS-137 Forward Looking Airborne Radar (FLAR) for its effectiveness in the U.S. Coast Guard's (USCG's) maritime search and rescue mission. The objectives of the AN/APS-137 FLAR evaluation are to:

a. Establish the search and rescue capabilities of Coast Guard HC-130 aircraft equipped with the AN/APS-137 FLAR,

b. Compare the AN/APS-137 FLAR performance to that of the AN/APS-127 FLAR, and

c. Develop operationally-realistic sweep widths and search guidance that search planners can use to conduct effective search and rescue missions under a variety of conditions.

The AN/APS-137 FLAR was evaluated onboard Coast Guard HC-130 fixed-wing aircraft from Coast Guard Air Station Clearwater, Florida. Data were collected during the 2-week experiment in the coastal waters off the west coast of Florida from Waccussa Bay to Gasparilla Island. This report discusses the detection performance of the AN/APS-137 FLAR against 4-, 6-, and 10-person life rafts and will provide search guidance based on this evaluation.

The evaluation was conducted by the USCG Research and Development (R&D) Center as part of the Improvement of Search and Rescue Capabilities (ISARC) Project.

2. HC-130 AN/APS-137 FLAR System Description

The HC-130 is a long-range surveillance aircraft used by the USCG for search and rescue, iceberg detection, law enforcement, fishery patrols, and marine environmental protection. The 'I/APS-137 FLAR was developed by Texas Instruments to detect small targets in a sea clutter environment. The AN/APS-137 FLAR is an X-band, air-to-surface Inverse Synthetic Aperture Radar (ISAR) that provides high resolution, small-target detection, weather avoidance, sea surveillance, and Doppler display. The FLAR system has special selectable features that enhance system performance against weak targets. These features were used to determine the search capability of the AN/APS-137 FLAR to detect life rafts. These features are:

- Periscope Search Mode - This mode is designed for low-altitude (3000 feet or lower), short-range [32 nautical miles (nmi) or less], high-resolution searches with an antenna scan speed of 300 revolutions per minute (rpm) and a pulse repetition frequency (PRF) of 2000 Hz. In this mode, sea clutter is significantly reduced, and the target returns are amplified to be more easily seen.

- Antenna Tilt Control - Provides automatic or manual variation of radar depression/elevation. Automatic tilt control sets the best depression/elevation angle based on aircraft altitude and range scale.

- Ground Stabilized Display Mode - This mode enables sea clutter suppression and is the best mode for small-target detection. Stationary or slow-moving target returns remain at a constant position on the Plan Position Indicator (PPI) while the aircraft moves across the screen.

- Range Scale - Larger range scales allow the target return to be on the screen longer, and smaller range scales allow for easier detection of short-range, weak target returns. The 16-nmi range scale was the primary scale used for this experiment. The 8- and 32-nmi range scales were used to a very limited extent to help evaluate the limits of the radar.

3. Approach

Data were collected using an operational Coast Guard aircraft with crews trained in AN/APS-137 FLAR use. Standard search patterns were used to search for randomly-placed targets within the search area. The search crews were not alerted to target locations.

A Differential Global Positioning System (DGPS) was used to monitor target and search craft positions. These positions were recorded on a laptop computer and on data logs maintained by test team observers. Target detections and human-factors data were logged by the observer onboard the search unit. Environmental data were logged onboard chartered workboats.

Environmental data buoys were deployed in the experiment area to record winds, sea conditions, and air/water temperatures.

Data reconstruction was performed to determine which target detection opportunities resulted in actual detections and at what lateral range each opportunity occurred. Raw data files were developed that included each target detection or missed opportunity along with the values of 13 search parameters of interest for each target opportunity. These data were analyzed on a desktop computer using a variety of statistical techniques including binary, multivariate regression analysis. Lateral range versus target detection probability plots and sweep width estimates were developed for search conditions that were well represented in the data. The search parameters were analyzed for their significance at the 90-percent confidence level.

Human-factors data were compiled and analyzed quantitatively where possible. Subjective comments by search unit crews and data recorders were synopsized and incorporated into the Conclusions and Recommendations section of this report.

RESULTS AND CONCLUSIONS

1. Results

A combined total of 507 life-raft detection opportunities were generated during this experiment. Table 1 provides a summary of the distribution of the detection opportunities by target type. Environmental and search conditions represented in the data are listed in table 2.

There was no significant difference in detection performance between life-raft types, and the life rafts were all evaluated as one data set.

Table 1. Summary of Distribution of Target Detection Opportunities by Target Type

Target Type	4-person Life Raft	6-person Life Raft	10-person Life Raft
Detection Opportunities	68	207	232

Table 2. Environmental and Search Parameters

Category	Parameter	Unit of Measure	Measured Range of Values
Target	type	life raft	N/A
	size	capacity	4,6,10
	lateral range	nautical miles	0 to15.9
SRU	search speed	knots	180 to 220
	search altitude	feet	1000, 1500, 2000
	range scale	nautical miles	8, 16, 32
	relative bearing	degrees	-120 to 120
Environment	precipitation	none(0)/light(1)/moderate(2)/heavy(3)	0, 1
	significant wave height	feet	1.6 to 3.6
	whitecap coverage	none(0)/light(1)/moderate(2)/heavy(3)	0, 1
	relative wave direction	into wave direction (+1) across wave direction (0) away from wave direction (-1)	-1, 0, 1
	windspeed	knots	2.9 to 13.0
Human Factors	time on task	hours	0 to 5.4

Lateral range plots and sweep width estimates were developed for the life rafts; the small-boat data set was not large enough to support an accurate sweep width estimate. Besides lateral range, significant wave height (H_S) was also identified as a significant variable affecting life-raft detection. The life-raft data set was grouped into the following two data sets:

- H_S less than or equal to 2.5 feet, and
- H_S between 2.5 and 3.6 feet.

Although lower search altitudes were expected to improve detection performance in higher seas, search altitude was not identified as a significant variable. Search altitude correlated slightly with significant wave height, and the range of significant wave height values was relatively small. These two factors may have affected the results.

2. Conclusions

- The life-raft detection performance of the AN/APS-137 FLAR decreased steadily with increasing seas up to a significant wave height of 2.5 feet. Beyond a significant wave height of 2.5 feet, the detection probability leveled off with increasing H_S up to at least 3.6 feet.

- For significant wave heights up to 2.0 feet, the AN/APS-137 FLAR performed at least 50 percent better than the AN/APS-127 FLAR out to 4.0 nmi. For significant wave height conditions from 2.0 to 3.6 feet, the AN/APS-137 FLAR performed better than the AN/APS-127 FLAR out to 12 nmi. Beyond these ranges, the performances of the two FLARs are approximately the same.

- The AN/APS-127 FLAR in the 20-nmi range scale performed slightly better at 14 to 16 nmi than the AN/APS-137 FLAR. This is most likely due to the difference in the target on-screen time between the 16-nmi range scale and the 20-nmi range scale displays. It cannot be determined with this data set if the AN/APS-137 FLAR would perform better at longer ranges when using the 32-nmi range scales, or if the loss in resolution would degrade life-raft detection performance.

- In areas of even moderate contact density, visually verifying targets is not practical and will quickly degrade the efficiency of the search and possibly reduce search area coverage.

- The small-boat data set was too small to be able to draw any definite conclusions about the AN/APS-137 FLAR detection performance against small-boat targets.

3. Recommendations for AN/APS-137 FLAR Searches for Life Rafts

- The sweep widths in table 3 should be used to represent the detection performance of the AN/APS-137 FLAR against 4-, 6- and 10-person life raft targets.

Table 3. Sweep Widths for 4-, 6-, and 10-Person Life Rafts Using the AN/APS-137 FLAR

Range Scale (nmi)	Significant Wave Height (feet)	Sweep Width (nmi)
16	≤ 2.5	9
	2.5 to 3.6	7

- The 16-nmi range scale in periscope mode should be the primary range scale used when searching for life rafts.

- For significant wave heights up to 3.6 feet, when searching for life rafts, the radar operator should concentrate on the higher detection area of the display out to at least 12 nmi, even if the track spacing is less than 12 nmi. This is based on the assumptions used when deriving the value for sweep width.

- The AN/APS-137 FLAR operator should reposition the sweep origin of the display at intervals long enough to allow for an adequate search for weak contacts but short enough to be able to detect a contact as close to the maximum range of detectability as possible. For life-raft targets, this should be at approximately 1-minute intervals.

- The radar operator should turn the heading cursor off when searching for weak contacts.

4. Recommendations for Future Research

- Future tests should include small-boat targets of all sizes, from 20 feet to 50+ feet.

- Data should be collected for life rafts in low-sea conditions (significant wave heights less than 2.0 feet).

- Future tests should include data to study the effects on the operator of extended on-scope time versus detection performance. Previous data studied the overall effect of on-scene time on the entire aircrew.

- The effects of the search aircraft diverting its flight path to visually verify a contact may degrade overall search coverage. Alternate means of target verification/discrimination should be investigated.

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The authors would like to thank the many individuals from the numerous Coast Guard units that participated in this research effort. During the course of the field test, many people assisted in the set up and dismantling of support equipment, and the monitoring of communications. In particular, we would like to acknowledge the personnel from the following units, without whom the operational field test would not have been possible; Coast Guard District Seven, Air Station Clearwater, FL, Group St. Petersburg, FL, and Station Yankeetown, FL. We extend our special thanks to the personnel from the Aids to Navigation division, the Electronics shop, and the Communications division of Group St. Petersburg for providing logistical support for setting up the Differential Global Positioning System radio beacon on Egmont Key, and providing communications support throughout the field test. We also extend our thanks to the personnel of Station Yankeetown for providing logistical and communications services, and equipment storage facilities. We would also like to acknowledge the crews of the M/V Terri Lynn, M/V Jumpin' Jack Flash, F/V Blackjack III, F/V Blue Seas III, F/V Wantabe, and the F/V Doghouse for their assistance in life raft target deployment and recovery during the field test, and the M/V Seahorse and the tug provided by Townsend Marine for assisting in the deployment and recovery of the two environmental buoys.

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We would like to acknowledge the advice and critical review provided by Dr. David Paskausky during the planning and analysis phase of this field test.

We would also like to thank the many other personnel from the Coast Guard R&D Center and Analysis & Technology, Inc. who supported this research effort.

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CHAPTER 1
INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This report is the second in a series that will document the U.S. Coast Guard (USCG) Research and Development (R&D) Center's evaluation of the AN/APS-137 Forward Looking Airborne Radar (FLAR) capabilities for search and rescue missions. During the Spring 1991, a preliminary evaluation was conducted off the coast of Newfoundland, Canada to help establish the test parameters to be used during future experiments. From 30 March to 10 April 1992, the R&D Center tested the AN/APS-137 FLAR performance in the coastal waters off the west coast of Florida from Waccussa Bay to Gasparilla Island. The Coast Guard HC-130 long-range surveillance aircraft is equipped with the AN/APS-137 FLAR and was used to detect 4-, 6-, and 10-person life rafts. Workboats that deployed life rafts were used as targets of opportunity during each search; however, the data collected will not be analyzed in this report.

This evaluation of the AN/APS-137 FLAR is part of the R&D Center's Improvement of Search and Rescue Capabilities (ISARC) Project. The project objectives are to improve search planning and execution and to evaluate visual and electronic search methods, leeway drift, ocean current drift, and visual distress signals. Specific objectives of the AN/APS-137 FLAR evaluations are to:

1. Establish the search and rescue capabilities of Coast Guard HC-130 aircraft equipped with the AN/APS-137 FLAR,

2. Compare the AN/APS-137 FLAR performance to that of the AN/APS-127 FLAR, and

3. Develop operationally-realistic sweep widths and search guidance that search planners can use to conduct effective search and rescue missions under a variety of conditions.

1.2 HC-130 AN/APS-137 FLAR SYSTEM DESCRIPTION

The HC-130 is a long-range surveillance aircraft used by the USCG for search and rescue, iceberg detection, law enforcement, fishery patrols, and marine environmental protection. The

AN/APS-137 FLAR was developed by Texas Instruments and is used by the Coast Guard to detect small targets in a sea clutter environment. The AN/APS-137 FLAR is an X-band, air-to-surface inverse synthetic aperture radar that was developed to provide high resolution, small-target detection, weather avoidance, sea surveillance, and Doppler display. Detailed information and principals of operation can be found in references 1 and 2. The following features were used to determine the search capability of the AN/APS-137 FLAR to detect life rafts.

- Periscope Search Mode - This mode is designed for low-altitude (3000 feet or lower), short-range [32 nautical miles (nmi) or less], high-resolution searches with an antenna scan speed of 300 revolutions per minute (rpm) and a pulse repetition frequency (PRF) of 2000 Hz. In this mode, sea clutter is significantly reduced, and the target returns are amplified to be more easily seen.

- Antenna Tilt Control - Provides automatic or manual variation of radar depression/elevation. Automatic tilt control sets the best depression/elevation angle based on aircraft altitude and range scale.

- Ground Stabilized Display Mode - This mode allows sea clutter suppression and is the best mode for small-target detection. Stationary or slow-moving target returns remain at a constant position on the Plan Position Indicator (PPI) while the aircraft moves across the screen.

- Range Scale - Larger range scales allow the target return to be on the screen longer. Smaller range scales allow for easier detection of short-range, weak target returns. The 16-nmi range scale was the primary scale used for this experiment. The 8- and 32-nmi range scales were used to a very limited extent to help evaluate the limits of the radar.

1.3 EXPERIMENT DESCRIPTION

From 30 March to 10 April 1992, a 2-week experiment was conducted in the coastal waters off the west coast of Florida from Waccussa Bay to Gasparilla Island. The following sections describe the experiment.

1.3.1 Participants

The USCG R&D Center, Avery Point, Groton, Connecticut conducted and controlled the AN/APS-137 FLAR evaluation Spring 1992 experiment. A full team of USCG R&D Center personnel and personnel from Analysis & Technology, Inc. (A&T), the prime contractor, were responsible for the overall conduct of the test, including the following:

- Equipment installation, operation, and maintenance,
  - MINIMET™ meteorological buoy
  - Differential Global Positioning System (DGPS) tracking systems
- Workboat coordination,
- Aircraft coordination,
- Communications and Control,
- Data collection, and
- Logistics.

USCG Air Station Clearwater provided the HC-130 aircraft equipped with the AN/APS-137 FLAR, the flight crews, and all of the necessary technical and administrative support personnel. The following HC-130 Search and Rescue Units (SRUs) participated in the experiment: CG 1716, CG 1416, and CG 1720. Air Station Clearwater also provided a mobile communications trailer that functioned as R&D Control. All experiment-related communications were relayed to R&D Control via Coast Guard Group St. Petersburg.

The Group St. Petersburg Aids-to-Navigation Team and Electronics Shop supported the DGPS installation at the radio beacon tower at Egmont Key. The Communications Division also provided communications support for all experiment participants.

Three separate commercial companies subcontracted workboat services to deploy the life rafts. Each workboat included a qualified Captain and a crew member with each workboat. The LCM "Seahorse" out of Venice, FL and the Townsend, Inc. tug out of Yankeetown, FL deployed the MINIMET™ environmental buoys. A field team coordinator was also onboard each workboat to record target positions and to assist in target deployment and recovery.

1.3.2 Search Area

The search area covered 4800 square miles and consisted of a northern and southern area separated by the Tampa Bay Safety Fairway. Figure 1-1 shows the search areas along the Gulf Coast of Florida. The northern area was a 40- x 80-nmi area centered at 28°25.0'N, 83°23.0'W along a major axis of 000°T. The southern area was a 40- x 40-nmi area centered at 26°55.0'N, 83°03.0'W along a major axis of 155°T. Each area was further divided into workboat sectors, and each of the six workboats was assigned a sector for distributing the targets. Life-raft targets were deployed throughout each sector according to random settings to ensure a near-uniform target density throughout the search area.

An operations center (R&D Control) was established at Air Station Clearwater. R&D Control was responsible for SRU and workboat coordination and supervision. When delays in the commencement of the search were encountered, R&D Control moved the western edge of the search area east by 10 nmi for every hour of delay. After a 4-hour delay, the exercise was canceled for the day.

1.3.3 Targets

There were three types of life rafts used during this experiment: 4-, 6- and 10-person life rafts, all equipped with canopies. Table 1-1 lists the targets and their descriptions.

1.3.4 Experiment Design and Conduct

This experiment was designed to characterize the detection performance of the AN/APS-137 FLAR against life raft targets in varying environmental conditions and to establish a data base to be built upon in future tests. Detection data were obtained using unalerted operators. A parallel search pattern, modified for the necessary skew of the southern search area, was followed. Track spacing for the parallel searches was set at 5 nmi and was based on initial detection range estimates that were determined during the Spring 1991 experiment. Figure 1-2 illustrates the search plan for the HC-130. The targets were placed at random positions throughout each workboat sector at an average target-to-target distance of approximately 8 nmi. The minimum target-to-target distance over the entire search area was 5 nmi. During the experiment, it was discovered that it took the slower workboats almost 6 hours to deploy/recover the life rafts. This time frame could be significantly shortened by minimizing the north-south (N-S) randomness of the target positions.

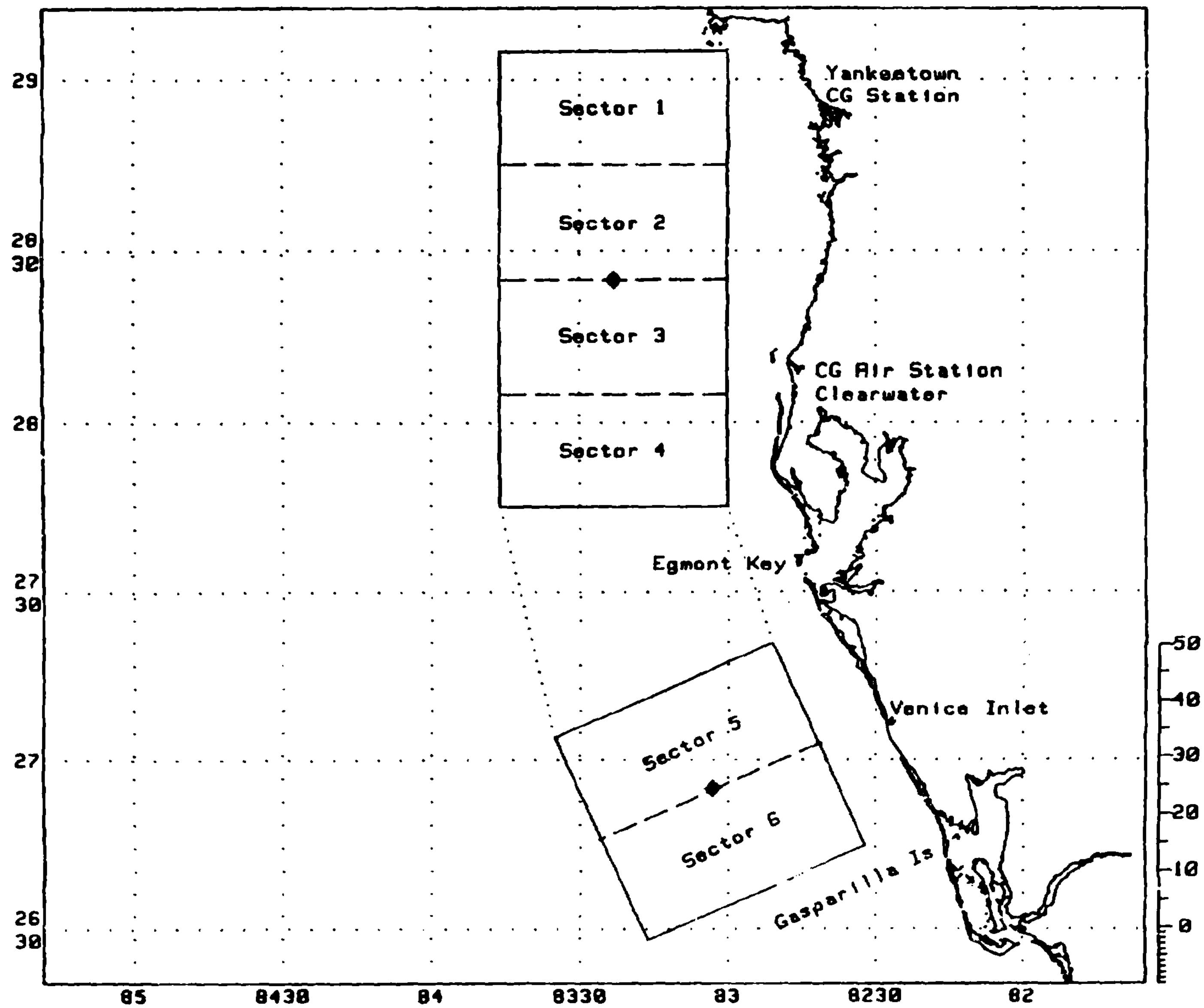

Figure 1-1. Search Area

Table 1-1. Description of Targets

Target	Quantity	Principal Material	Dimensions: (feet)	Description
Life Rafts	2	rubber/fabric	6.0 dia x 3.5*	4-person Avon w/Canopy
	1	rubber/fabric	5.5 sq. x 3.5	4-person Viking w/Canopy
	10	rubber/fabric	5.8 x 8.6 x 3.3†	6-person Switlick w/Canopy
	3	rubber/fabric	8.6 x 5.8 x 3.6	6-person Avon w/Canopy
	10	rubber/fabric	7.8 x 10.8 x 4.2	10-person Switlick w/Canopy
	2	rubber/fabric	9.2 dia x 5.2	10-person BF Goodrich w/Canopy

* outside dimensions x height
† length x breadth x height

The short detection range of the radar, when searching for life-raft targets, allowed the N-S positions of the life-raft targets to be restricted to within 5 nmi of the centerline of the workboat sector and still not have a pattern appear on the scope. Because the radar operator did not know any of the target positions, the restriction of the raft positions did not violate the assumptions of random target distribution.

The HC-130 typically searched at an altitude of 1500 feet and at speeds ranging from 180 to 220 knots. The planned speed of 240 knots was too fast and was changed early in the first search to 220 knots. The first search also concentrated on reporting all contacts. In areas of high-contact density, recording the contacts by hand made it difficult to accurately record the time (to the nearest second), range, and bearing before the next contact was called. To reduce the workload on the data recorder, subsequent searches used a priori knowledge of what life-raft and small-boat detections looked like to discriminate obviously large targets (tankers/merchants) from small ones (life rafts/small boats).

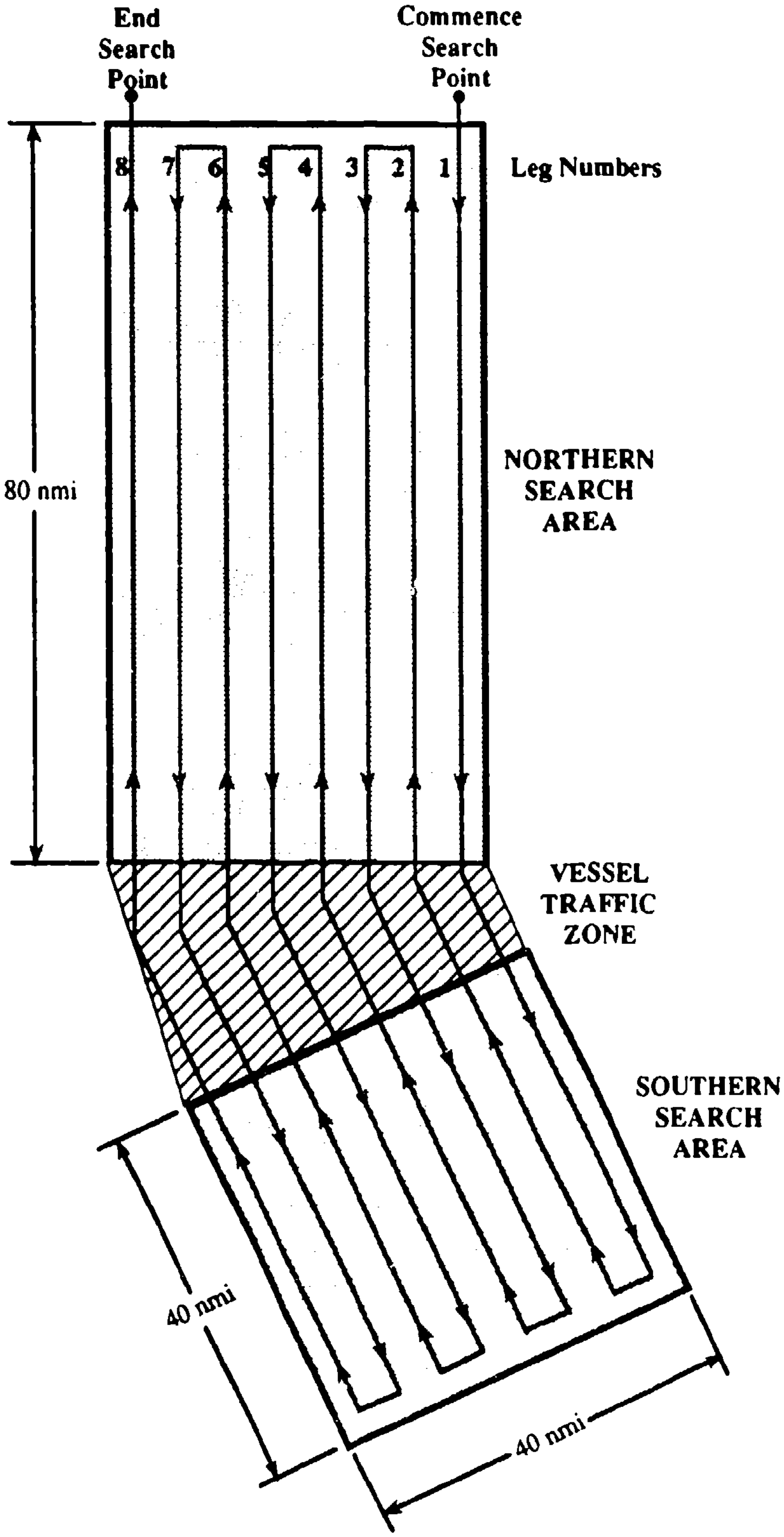

Figure 1-2. Aircraft Search Plan

The HC-130 crew consisted of personnel from the normal complement at Air Station Clearwater. All of the radar operators were experienced in the use of the AN/APS-137 FLAR, and their experience level is representative of the current AN/APS-137 FLAR experience in the Coast Guard. During the experiment, the crews were encouraged to treat the search as an actual search and rescue mission with the exception that lookouts did not alert the radar operator to any visual contacts. Also, the SRU did not deviate from the search track, and the radar operator would not switch to IMAGE mode in order to verify a target.

On the morning of each search day, the workboats departed from their respective ports and deployed all of the targets by approximately 12 o'clock. A data recorder accompanied each workboat to assist in target deployment/recovery and to record navigational and environmental data. The HC-130 took off from Air Station Clearwater to be at the Commence Search Point (CSP) when the workboats were approximately half-way through the search area and outside the range scale of the AN/APS-137 FLAR. A data recorder accompanied each flight to record target detections, human factors, crew comments, and any other relevant information.

When a target was detected, the radar operator reported the target's range and true bearing, and the data recorder recorded the information and the time of detection to the nearest second. For this experiment, some of the data were also automatically recorded by the Airborne Data Acquisition Management (ADAM) system, a temporarily-installed system onboard the HC-130. ADAM recorded time, true bearing, range, and the aircraft position [according to the aircraft Inertial Navigation System (INS)] for each target tag.

During the search, a video recording was made of the radar PPI display. These tapes were used in reconstruction to help resolve life-raft or workboat detections when a question arose from the reconstructed SRU-target positions.

On-scene environmental conditions were recorded manually by the experiment observers on the workboats and automatically by the MINIMET™ meteorological buoys placed in the search areas. The observers onboard each workboat recorded environmental data on the Environmental Conditions Summary Form (figure 1-3) using the equipment installed on each workboat.

Two MINIMET™ buoys were deployed during the experiment, one at the midpoint of the northern area and one at the midpoint of the southern area. These environmental buoys were the preferred method of measuring environmental conditions. Each buoy transmitted data, by means of a satellite uplink, to the International Ice Patrol. R&D Control received these data via land line,

ENVIRONMENTAL CONDITIONS SUMMARY

Workboat Name:________________ Date:________________

TIME	SURFACE WIND		CLOUD COVER (tenths)	CLOUD CEILING (ft)	VISIBILITY *(nmi)*	WEATHER DESCRIPTION *(clear, rain, fog, etc.)*	SEA STATE			AIR TEMP (°C)	WATER TEMP (°C)
	TRUE SPEED (knots)	TRUE DIRECTION (° true)					Hs* (ft)	WHITE CAPS (N/S/M)	SWELL DIR (° true)		
**METHOD OF MEASUREMENT											

*Significant wave height

Note: Method may be scientific (anemometer, radar, psychrometer, etc.) or an estimate. Indicate method used to measure each parameter.

OBSERVER________________

Figure 1-3. Sample Environmental Conditions Summary Form and the data were used as a factor in deciding if sea conditions were safe enough to deploy the targets[1]. The MINIMET™ information was also stored on magnetic storage media onboard the buoy as a backup to the transmitted data. The data were used later during the data analysis to determine the significant variables that affect detection. Figure 1-4 is an example of the data messages received from the buoy.

1.3.5 Tracking and Reconstruction

The primary method of obtaining position data for all SRU and target crafts was DGPS. As a backup, each workboat used LORAN-C and the aircraft used its INS. The DGPS used a central master station (Egmont Key) for all experiment participants. Prior to each search, the secondary navigation system onboard each vessel/aircraft was initialized or compared to the DGPS position, establishing a tie point for each vessel. During the period that the experiment was run, DGPS outages occurred regularly for periods ranging from 45 minutes to 1 hour. When DGPS was unavailable, the tie points were used to reconstruct the position of the vessel or aircraft.

Each workboat deployed five life rafts. These rafts were anchored in 100 to 200 feet of water with 8- or 12-lb Danforth anchors. When each life raft was deployed and recovered, the time and DGPS position was recorded. If the positions differed from deployment to recovery, the assumed life raft position at the time of possible detection was a linear interpolation between the two positions.

The HC-130 search track and the workboat and life-raft target positions were reconstructed from the recorded position data (DGPS, INS, and LORAN-C) and plotted on quadrille ruled paper using an HP GL plotter. Figure 1-5 is an example of a reconstructed plot. Each target is designated by a letter. The HC-130 search track is shown as a series of dots (•). A hard copy text printout of the actual positions and times along the search track was available to help in reconstruction.

A target was considered a detection opportunity if its lateral range [measured as the closest point of approach (CPA) to the aircraft search track] was within the 16-nmi range scale. Previous analysis of the Spring 1991 data concluded that small radar cross-section targets (i.e., life rafts) were rarely detected beyond 13 nmi. It was expected that the workboats would be very detectable at 16 nmi; however, because they were secondary to the life-rafts, it was decided not to increase the range scale used during the search just to detect the workboats.

---

[1] The criteria for cancelling the day's search was 20-knot winds and 4-foot seas; the workboat captains made the final decision on whether or not to deploy the targets.

007E0820AEE11190019203291110040116040250235046190018717126552366830290661018928225999

Buoy: 901 Date/Time: 29 Mar 1992 / 11:10:00 MET Data

Lat/Lon: 26°55.24'N / 83°02.91'W

Vec Wind Spd: 4.0 m/s (7.8 kts)	Air Tem: 18.7° C (65.7°F)
Vec Wind Dir: 129° M	Barometric Pres: 1,018.9 mb
Avg Wind Spd: 4.0 m/s (7.8 kts)	Water Temp: 19.0° C (66.2°F)
Max Wind Spd: 4.6 m/s (8.9 kts)	S4 Current Spd: 828 cm/s (16.1 kts)
Last Buoy Azimuth: 250° M	S4 Current Dir: 225° M
Last Vane Reading: 235° M	S4 Spare Reading: 9999
Battery Voltage: 17.1 vdc	

007F08202E22290192032911069106110100087100091097079085108107130139183178156166155181176190106221241228217236240249255243002005009

Buoy: 901 Date/Time: 29 Mar 1992 / 11:30:00 WAVE Data

Scaled Spectral Values 1-16

069 106 110 100 087 100 091 097 079 085 108 107 130 139 183 178

Scaled Spectral Values 17-32

156 166 155 181 176 190 196 221 241 228 217 236 240 249 255 243

Scale: 2 Sign. Height: 0.5 m (1.6 ft) Max Period: 0.9 sec

00800820FE111901920329114003611003725321504319018717126552344830291501019282822599999

Buoy: 901 Date/Time: 29 Mar 1992 / 11:40:00 MET Data

Lat/Lon: 26°55.23'N / 83°02.92'W

Vec Wind Spd: 3.6 m/s (7.0 kts)	Air Tem: 18.7° C (65.7°F)
Vec Wind Dir: 110° M	Barometric Pres: 1,019.2 mb
Avg Wind Spd: 3.7 m/s (7.2 kts)	Water Temp: 19.0° C (66.2°F)
Max Wind Spd: 4.3 m/s (8.4 kts)	S4 Current Spd: 828 cm/s (16.1 kts)
Last Buoy Azimuth: 253° M	S4 Current Dir: 225° M
Last Vane Reading: 215° M	S4 Spare Reading: 9999
Battery Voltage: 17.1 vdc	

00810822BE1119019203291210038114038258210045190187171265522718302931410194828225999

Buoy: 901 Date/Time: 29 Mar 1992 / 12:10:00 MET Data

Lat/Lon: 26°55.23'N / 83°02.93'W

Vec Wind Spd: 3.8 m/s (7.4 kts)	Air Tem: 18.7° C (65.7°F)
Vec Wind Dir: 114° M	Barometric Pres: 1,019.4 mb
Avg Wind Spd: 3.8 m/s (7.4 kts)	Water Temp: 19.0° C (66.2°F)
Max Wind Spd: 4.5 m/s (8.7 kts)	S4 Current Spd: 828 cm/s (16.1 kts)
Last Buoy Azimuth: 258° M	S4 Current Dir: 225° M
Last Vane Reading: 210° M	S4 Spare Reading: 9999
Battery Voltage: 17.1 vdc	

00820820E22290192032912090114121105106094096088102095092100115142151162157159160171158163156191220244255251240223422423300300601 0

Buoy: 901 Date/Time: 29 Mar 1992 / 12:30:00 WAVE Data

Scaled Spectral Values 1-16

090 114 121 105 106 094 096 088 102 095 092 100 115 142 151 162

Figure 1-4. Example MINIMET™ Data Message

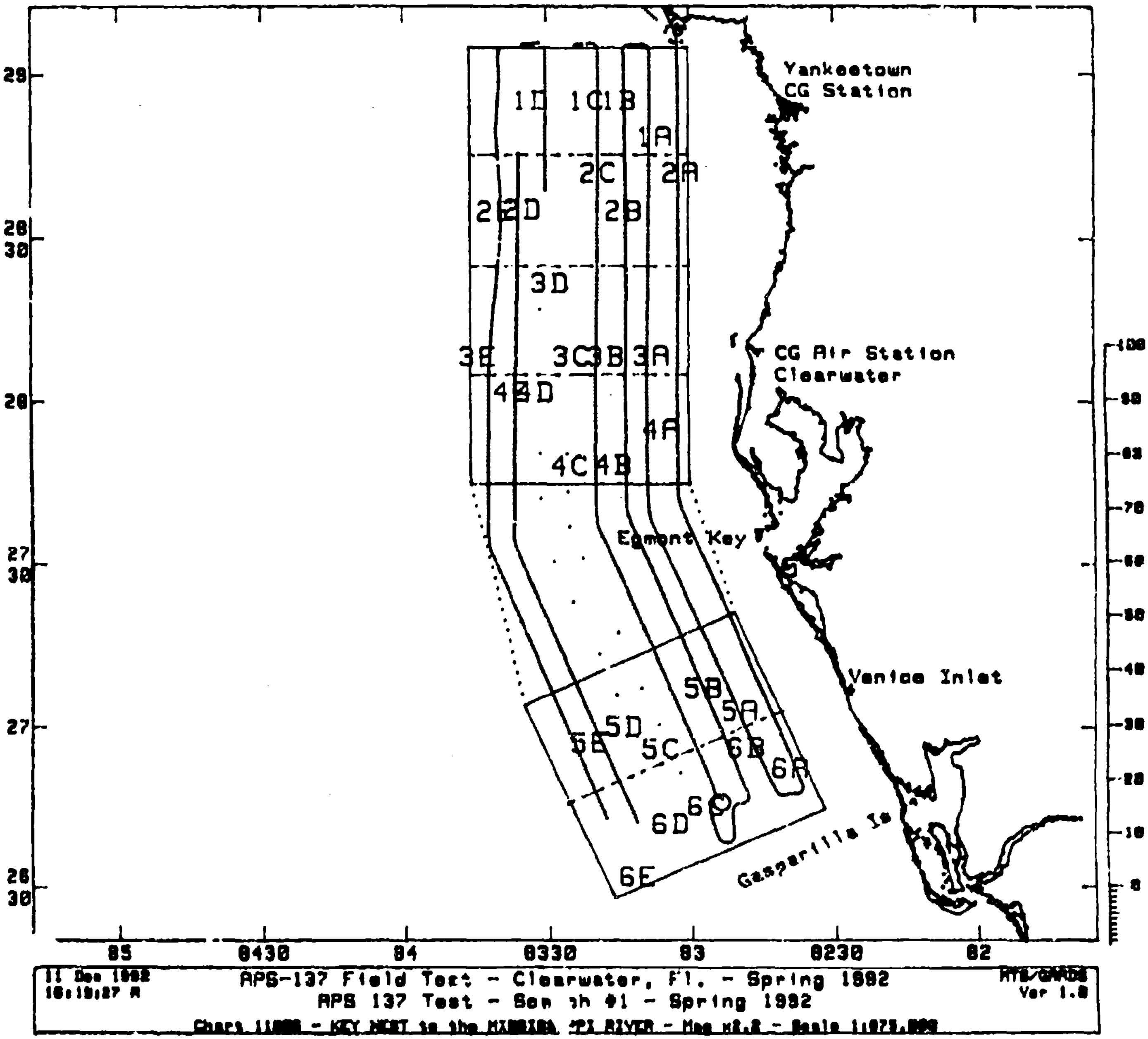

Figure 1-5. Example of Reconstructed Search Plot

The radar contacts were correlated to actual target positions by comparing target bearing and range from the HC-130 position to the actual target positions. A target that was an opportunity but not detected was recorded as a miss.

1.3.6 Search Parameters

A total of 13 search parameters were recorded for each target detection opportunity. The parameters were categorized as target, SRU, environment, or human factors related and are described in table 1-2.

Table 1-2. Search Parameters

Category	Parameter	Unit of Measure	Measured Range of Values
Target	type	life raft	N/A
	size	capacity	4,6,10
	lateral range	nautical miles	0 to15.9
SRU	search speed	knots	180 to 220
	search altitude	feet	1000, 1500, 2000
	range scale	nautical miles	8, 16, 32
	relative bearing	degrees	-120 to 120
Environment	precipitation	none(0)/light(1)/moderate(2)/heavy(3)	0, 1
	significant wave height	feet	1.6 to 3.6
	whitecap coverage	none(0)/light(1)/moderate(2)/heavy(3)	0, 1
	relative wave direction	into wave direction (+1) across wave direction (0) away from wave direction (-1)	-1, 0, 1
	windspeed	knots	2.9 to 13.0
Human Factors	time on task	hours	0 to 5.4

1.4 ANALYSIS APPROACH

1.4.1 Sweep Width Measure of Search Performance

The primary performance measure used by search and rescue mission coordinators to plan searches is sweep width (W). Because this evaluation supports improved Coast Guard search and rescue mission planning, the measure of search performance for this analysis is also sweep width. Sweep width is a single-number summation of a more complex range/detection probability relationship. Mathematically,

$$W = \int_{-\infty}^{\infty} P(x)\,dx$$

where

x = Lateral range (see figure 1-6), and

P(x) = Target detection probability at lateral range x.

Figure 1-7 shows a typical P(x) curve as a function of lateral range. In this figure, x is the lateral range of detection opportunities.

Conceptually, sweep width is the numerical value obtained by choosing a value of lateral range that is less than the maxim ım detection distance for any given sweep, such that the number of scattered targets that might be detected beyond the chosen value of lateral range is equal to the number that might be missed which are closer than the chosen lateral range. Figure 1-8 (I and II) illustrates this concept. The number of targets missed inside the distance W is indicated by the shaded portion - area A. The number of targets detected beyond the distance W out to the maximum detection range (MAX R_D) is indicated by the shaded portions at the tails of the curve - areas B. Sweep width is defined when the number of targets missed inside of W equals the number detected outside of W (area A = sum of areas B). A detailed mathematical development and explanation of sweep width can be found in reference 3.

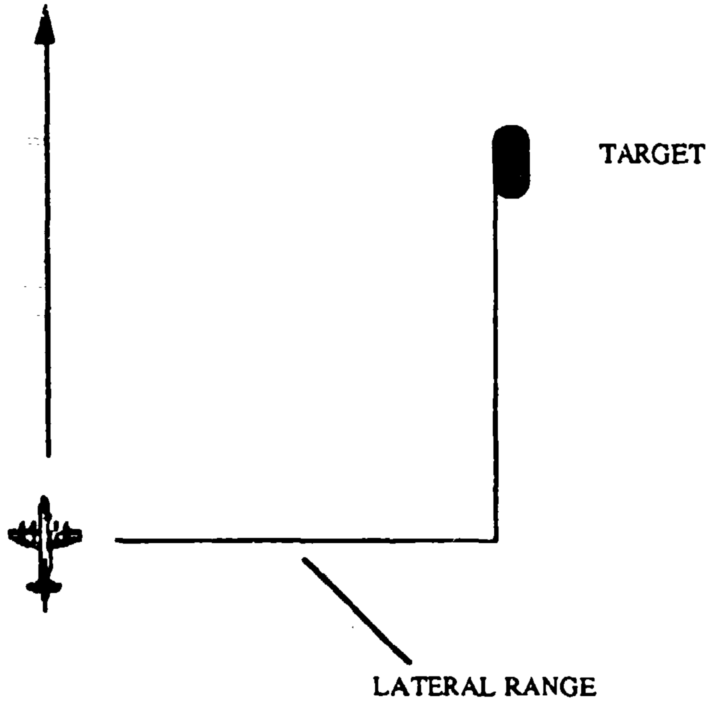

Figure 1-6. Definition of Lateral Range

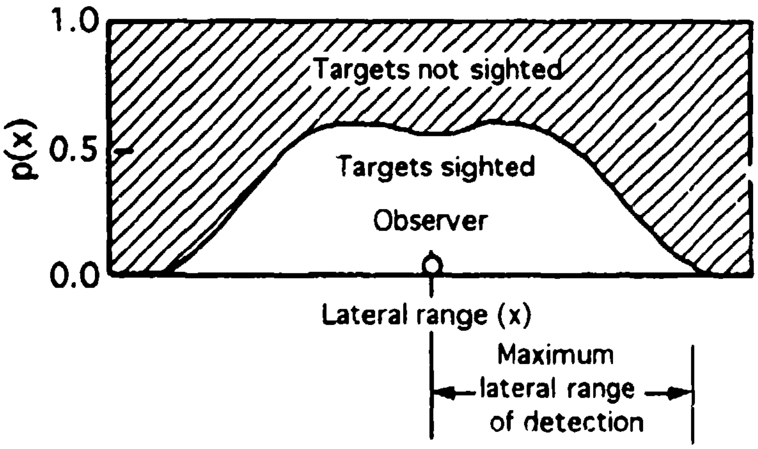

Figure 1-7. Relationship of Targets Detected to Targets Not Detected

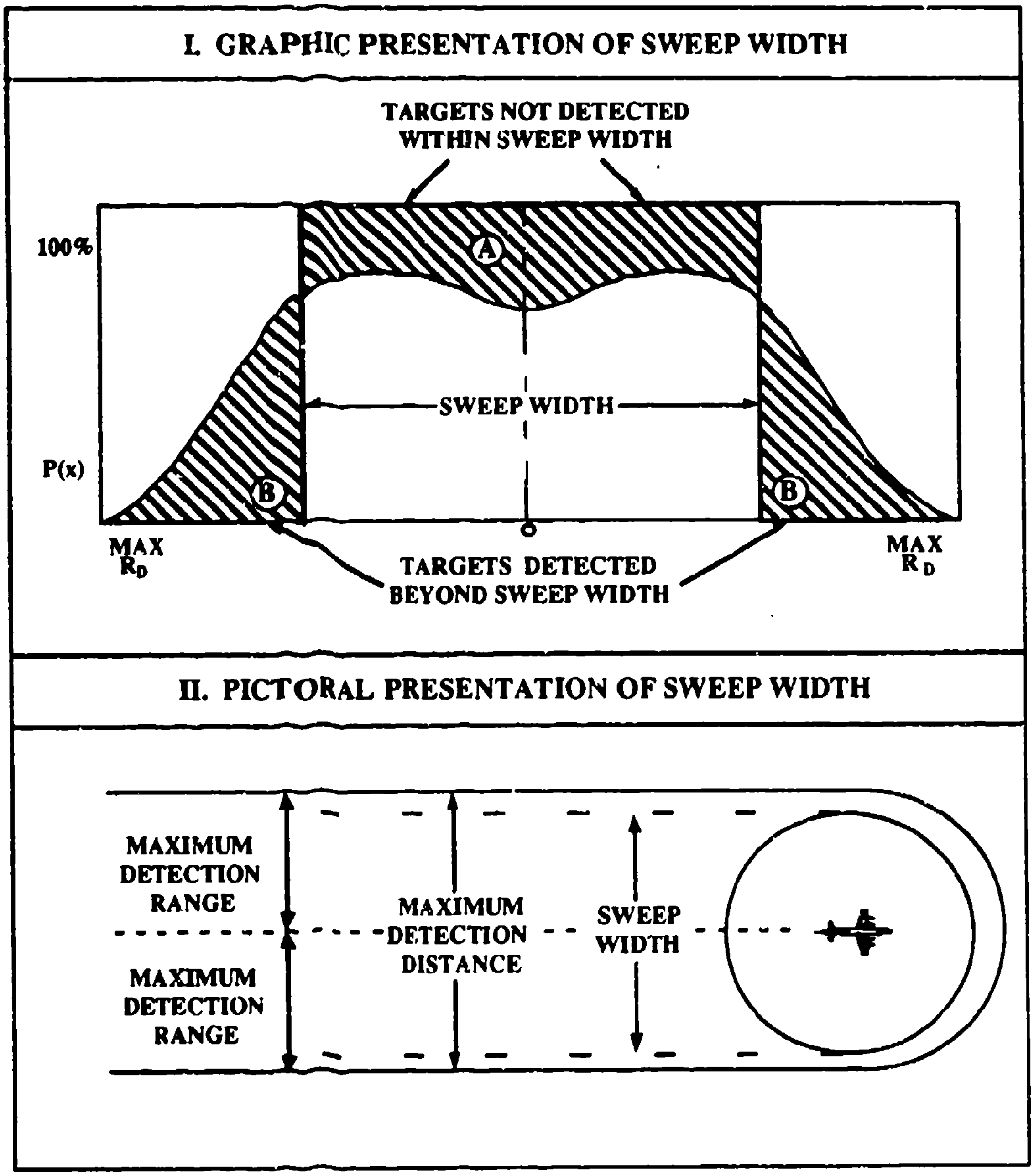

Figure 1-8. Graphic and Pictoral Presentation of Sweep Width

1.4.2 Analysis of Raw Data

Multivariate logistic regression has typically been used for electronic search to determine the significant variables for detection and the best curve fit for a monotonically decreasing data distribution. This method, however, cannot be used (without some constraints) for airborne radar detection data, which are peaked or unimodal. Once the constraints are applied and the significant variables identified, least squares linear regression must be used, for a given theoretical model of the data distribution, to determine a best fit curve.

1.4.2.1 **Development of Raw Data.** The reconstructed plots, AN/APS-137 FLAR detection logs, and recorded radar displays were used to determine which SRU-target encounters were valid detection opportunities and which opportunities resulted in successful target detections. Each target detection opportunity and detection miss was recorded, along with the corresponding search parameter values, into EXCEL spreadsheets for further analysis using SYSTAT, a statistical analysis package installed on an Apple Macintosh IIcx.

1.4.2.2 **Data Sorting and Statistics.** The data sorting, statistical calculations, and plots were done using SYSTAT. The search runs were combined to form one composite data set. The search parameters were plotted as histograms and scatter plots and the minimum, maximum, mean, and standard deviation were calculated to determine the high-level statistics for each parameter. The search parameters that were well represented over the range of values were chosen. These parameters were then used to statistically characterize the AN/APS-137 FLAR performance. Once the parameters to be analyzed were chosen, logistic multivariate regression analysis determined which of those search parameters exerted significant influence on detection performance at a 90-percent confidence level. These parameters were used to separate the data into groups based on the effects of each significant variable on detection performance. The logistics regression was performed using LOGIT, an add-on module to SYSTAT.

1.4.2.3 **LOGIT Multivariate Regression Model.** Multivariate logistic regression models have been proven effective for analyzing Coast Guard electronic and visual search data when the dependent variable is a discrete response (i.e., detection/no detection). The LOGIT multivariate regression model quantified the relationship between independent variables (x_i) and a probability of interest, R (the probability of detecting a target). The independent variables (x_i) can be continuous (e.g., wave height, wind speed) or binary (e.g., high/low altitude, SRU type 0 or 1). Lateral range is normally the most significant variable in determining radar probability of detection. However, inspection of the raw data for many target/sensor/range scale combinations indicated that the monotonic curve shape to which the LOGIT model is constrained would not adequately represent the observed radar detection performance as a function of lateral range. Figures 1-9 and 1-10 illustrate the problem encountered. Whereas the LOGIT model attempts to fit a monotonically increasing or decreasing S-shaped lateral range curve similar to those illustrated in figure 1-9, the raw data in most cases indicated that the unimodal (or peaked) lateral range curve shape depicted in figure 1-10 was more appropriate. LOGIT could be used to identify variables, other than lateral range, that were significant in determining probability of detection.

The equation for target detection probability used in the logistic regression model is:

$$R = \frac{1}{1 + e^{-\lambda}}$$

where

$R =$	target detection probability for a given searcher - target encounter,
$\lambda =$	$a_0 + a_1x_1 + a_2x_2 + a_3x_3 + ... + a_nx_n$,
$a_i =$	fitting coefficients (determined by computer program), and
$x_i =$	independent variable.

Maximum log-likelihood optimizes the a_i coefficients. A detailed theoretical development of the logistic regression analysis methodology is found in references 4 and 5.

A logistic regression model has advantages over other regression models and statistical methods.

1. The model implicitly contains the assumption that $0 \leq R \leq 1.0$; a linear model does not contain this assumption unless it is added to the model (in which case computation can become very difficult).

2. The model is analogous to normal-theory linear models. Therefore, analysis of variance and regression implications can be drawn from the model.

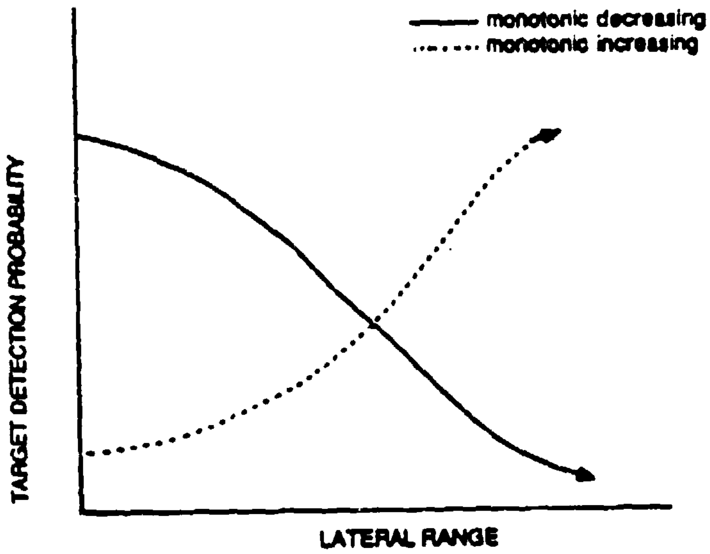

Figure 1-9. S-Shaped Curves

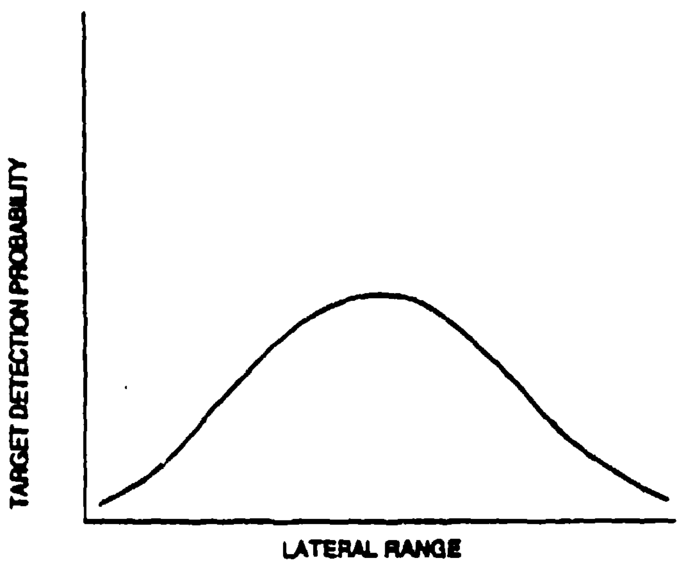

Figure 1-10. Unimodal Curve

3. The model can be used to observe the effects of several independent or interactive parameters that are continuous or discrete, even for distributions that do not obey the inverse cube law of detection.

4. A regression technique is better than nonparametric hypothesis testing, which does not yield quantitative relationships between the probability in question and the independent variables.

The primary disadvantage of a logistic regression model is that for the basic models, the dependent variable (R) must be a monotonic function of the independent variables. This limitation can sometimes be overcome by employing appropriate variable transforms (reference 4).

The AN/APS-137 FLAR detection data were analyzed on a Macintosh IIcx desktop computer with LOGIT software. LOGIT uses maximum log-likelihood to determine the influence of various independent explanatory variables in a discrete-choice response. The t-statistics output indicated the significance of these explanatory variables as predictors of the response (reference 5).

Using all of the chosen analysis parameters as a starting point, iterative use of the LOGIT regression model on each data set fit a function that contained only those search parameters that exerted a statistically-significant influence on the target detection response. The variables that were evaluated for this data set were those listed in table 1-2 that were well represented over a wide enough range of values to present a meaningful analysis. Those variables that had previously demonstrated a significant influence on AN/APS-131 Side-Looking Airborne Radar (SLAR) and AN/APS-127 FLAR search performance (reference 6) were also evaluated for significance in the data set.

1. Wind speed,
2. Significant wave height[1],
3. Search altitude,
4. Relative swell direction,
5. Target type and size,
6. Time-on-task, and
7. Whitecap coverage.

[1] Significant wave height is defined in reference 7 as the height (in feet) an experienced observer will give when visually estimating the height of waves at sea.

Controllable variables, other than those previously listed, were either held constant or adjusted as required by the sensor operators to achieve optimum small-target detection performance. Such variables were not considered in the data analysis.

1.4.2.4 Least-Squares Curve Fits. In order to fit a lateral range curve to the detection data that exhibited unimodal response, an appropriate fitting function had to be identified. During analysis of the previous FLAR and SLAR data, it was found that the function

$$P(x) = \frac{A^C}{(x - B)^2 + A^D},$$

where A, B, C, and D are regression variables and x is lateral range, could be fitted satisfactorily to all of the unimodally behaved data sets using the Simplex least-squares regression method (see reference 6). This technique was used to develop the lateral range curves and sweep widths that appear in chapter 2.

Although necessary to accommodate the unimodal curve shapes, the least-squares regression method previously described is a less satisfactory means of analyzing detection data than the LOGIT regression method. Specifically, the least-squares method has the following limitations that LOGIT does not.

1. The least-squares technique fits a function to a single, independent variable only (lateral range in this case), instead of to multiple parameters of interest. The effects of other parameters cannot be identified or quantified.

2. The binary detection/miss data must be binned into lateral range intervals, each of which should contain a reasonable number of detection opportunities before being entered into the regression model.

3. The least-squares regression variables (A, B, C, and D) have no physical significance relative to the detection process: they simply serve to adjust the fitting function's response to the independent variable lateral range.

4. The least-squares method of curve fitting is very sensitive to data outliers.

These limitations require that the detection data be subjected to a multistep analysis using the LOGIT regression model initially to identify variables, other than lateral range, that exerted significant influence on target detection probability. Variables identified as significant during this LOGIT analysis were grouped into meaningful levels to create data subsets that were, in turn, binned on lateral range. Finally, the x-y pairs of lateral range and target detection probability obtained in this manner were input to a computerized, least-squares regression program along with reasonable starting estimates for the regression variables A, B, C, and D. Using this three-step process, lateral range curve functions were developed for various combinations of the significant search parameters.

LOGIT assumes the inverse cube law of detection, and though this leads to a monotonically decreasing probability function of lateral range, the inverse cube law falls sufficiently in the middle of all the detection probability functions that it can be used for most empirical data (reference 3).

1.4.2.5 __Sweep Width Calculations__. The lateral range functions obtained from the procedures described in sections 1.4.2.4 were integrated over the range scale to obtain sweep width estimates for the AN/APS-137 FLAR under given environmental conditions. The integral of the unimodal function is:

$$W = \frac{A^C}{\sqrt{A^D}} \arctan\left(\frac{x - B}{\sqrt{A^D}}\right)\Bigg|_{x = -\infty}^{x = \infty},$$

or given the limits of the radar

$$W = 2 * \frac{A^C}{\sqrt{A^D}} \arctan\left(\frac{x - B}{\sqrt{A^D}}\right)\Bigg|_{x = 0}^{x = x_{max}},$$

where

W	=	sweep width,
A, B, C, and D	=	least squares fitted variables, and
x_{max}	=	the range scale of the radar.

For sufficiently large data sets, the sweep width can also be calculated with reasonable assurance of accuracy using the Simpson's 1/3 rule numerical integration method.

CHAPTER 2
TEST RESULTS AND ANALYSIS

2.1 INTRODUCTION

The data analysis discussed in sections 2.2 and 2.3 covers the quantitative results of the sweep width calculations and the qualitative evaluations of human factors on search performance, respectively. A total of 507 life-raft target detection opportunities were generated during this experiment using 4-, 6-, and 10-person life rafts. Table 2-1 provides a summary of the number of target detection opportunities by the target type. Appendix A contains the reconstructed data file of missed and detected opportunities for the life-raft data set. Appendix B contains the values for the non-linear regression coefficients that define the lateral range curves.

Although, in theory, search altitude should have affected detection performance, it was not a significant variable for this data set. Search altitude correlated slightly with significant wave height, and the range of significant wave height values was relatively small. These two factors may have affected the results.

The analysis showed no significant difference, at the 99+ percent confidence level, for AN/APS-137 FLAR target detection performance versus life-raft size, and so the life rafts were evaluated as one data set.

During testing on 10 April, the radar operators conducted the search notably different from the other searches. Search detections were only made out to 4.9 nmi compared to 13 nmi on the other days. The mean detection range was 4.7 nmi compared to 8.5 nmi on the other days. On further examination, it was noted that the environmental conditions for this day were not markedly different from the other days and did not contribute to this discrepancy. It was thought that the operator felt constrained to searching only out to one track spacing. The results for this day are so significantly different than the results for any other day that they are not included in this evaluation.

Table 2-1. Summary of Distribution of Target Detection Opportunities by Target Type

Target Type	4-person Life Raft	6-person Life Raft	10-person Life Raft
Detection Opportunities	68	207	232

2.2 DETECTION PERFORMANCE - LIFE-RAFT TARGETS

Sections 2.2.1 presents results of the sweep width analysis of the AN/APS-137 FLAR against life-raft targets. Section 2.2.2 presents results of the comparison of the AN/APS-137 FLAR to that of the AN/APS-127 FLAR. Lateral range curves and sweep width estimates for each target type are provided for search parameter combinations that were sufficiently represented in the data. Lateral range was identified as a significant search parameter for all combinations and is the variable of most concern when planning a search.

The lateral range plots show lateral range versus the probability of detection within a specified lateral range window. Figure 2-1 is an example of a lateral range plot with a key to the plot. Each probability plotted is denoted by a diamond (♦) corresponding to the detection opportunity ratio associated with each lateral range bin. The vertical bar through each "♦" denotes the 90-percent confidence interval for the data within the bin. The position of the "♦" along the horizontal axis corresponds to the average lateral range within each lateral range bin.

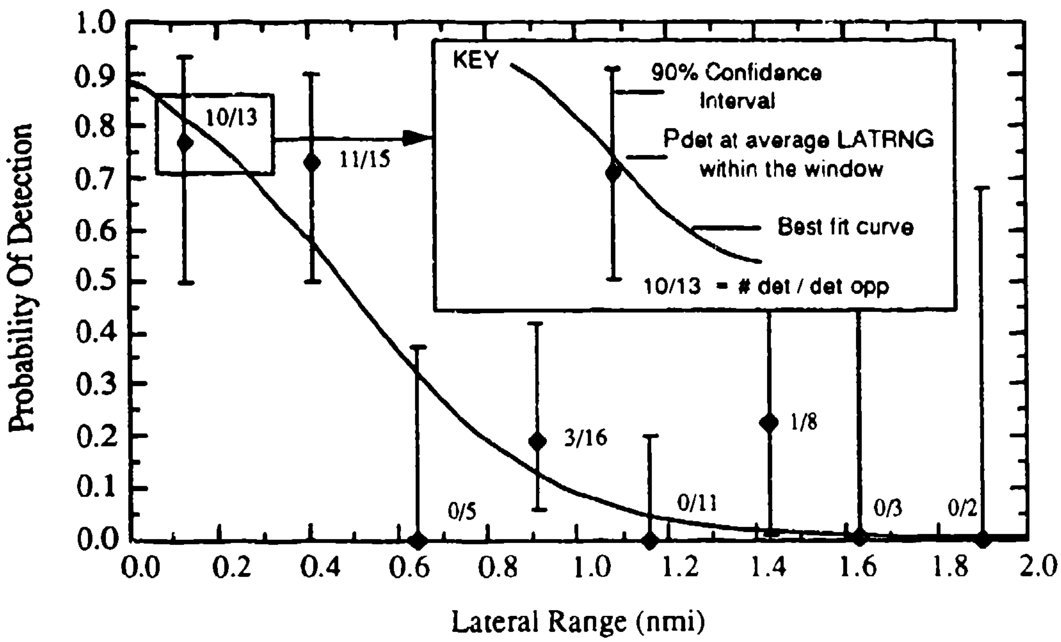

Figure 2-1. Example of Lateral Range Plot

2.2.1 AN/APS-137 FLAR Performance

Figures 2-2 through 2-3 show lateral range versus probability of detection data and the least-squares fitted curves for AN/APS-137 FLAR detection of all life-raft targets. Lateral range and significant wave height (H_S) were determined to be the search variables that had a significant influence at the 90-percent confidence level on the target detection probability. When probability of detection was plotted against H_S, increasing H_S steadily decreased the probability of detection. When H_S was less than or equal to 2.5 feet, this decrease was significant; however, beyond 2.5 feet the effect levels off and increasing H_S up to at least 3.6 feet did not have as much effect (see figure 2-4). Because 2.5 feet was a breakpoint for equitable distribution of the data, the data were broken into two data subsets:

$H_S \leq 2.5$ feet (210 opportunities), and
2.5 feet $< H_S \leq 3.6$ feet (297 opportunities).

Each data subset was analyzed to determine sweep width characteristics.

Figure 2-2 illustrates the results of the AN/APS-137 FLAR performance where H_S was less than or equal to 2.5 feet. The results show a peak at 2.7 nmi with a probability of detection equal to 0.54. Probability of detection then decreased fairly steadily to the edge of the range scale. No detections were made at lateral ranges greater than 13 nmi.

The AN/APS-137 FLAR performance, where H_S is between 2.5 and 3.6 feet (figure 2-3), was just slightly worse than in the lower H_S data subset. The data for H_S between 2.5 and 3.6 feet peaked for a lateral range of 1.6 nmi with a probability of detection equal to 0.48. Probability of detection dropped off dramatically beyond 10 nmi, where only one detection out of 81 opportunities was made.

The results of the sweep width analysis are as follows:

(1) W = 8.8 nmi ($H_S \leq 2.5$ ft), and
(2) W = 7.2 nmi (2.5 ft $< H_S \leq 3.6$ ft).

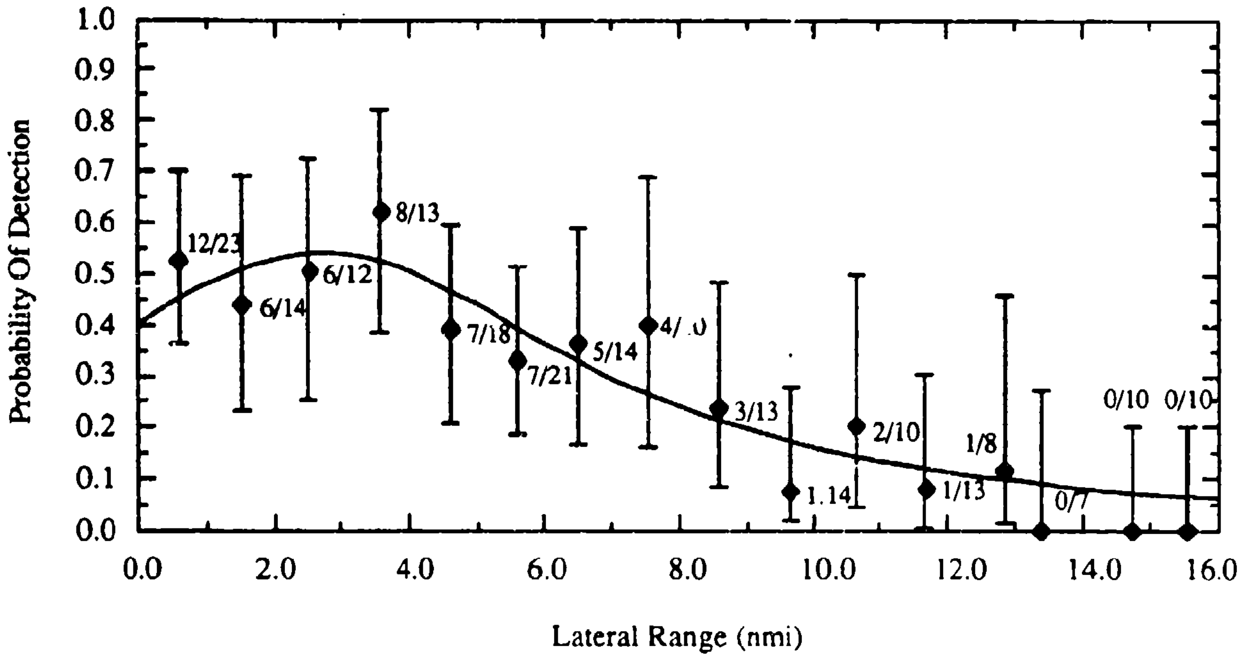

Figure 2-2. AN/APS-137 FLAR Detection of Life Rafts ($H_S \leq 2.5$ ft)

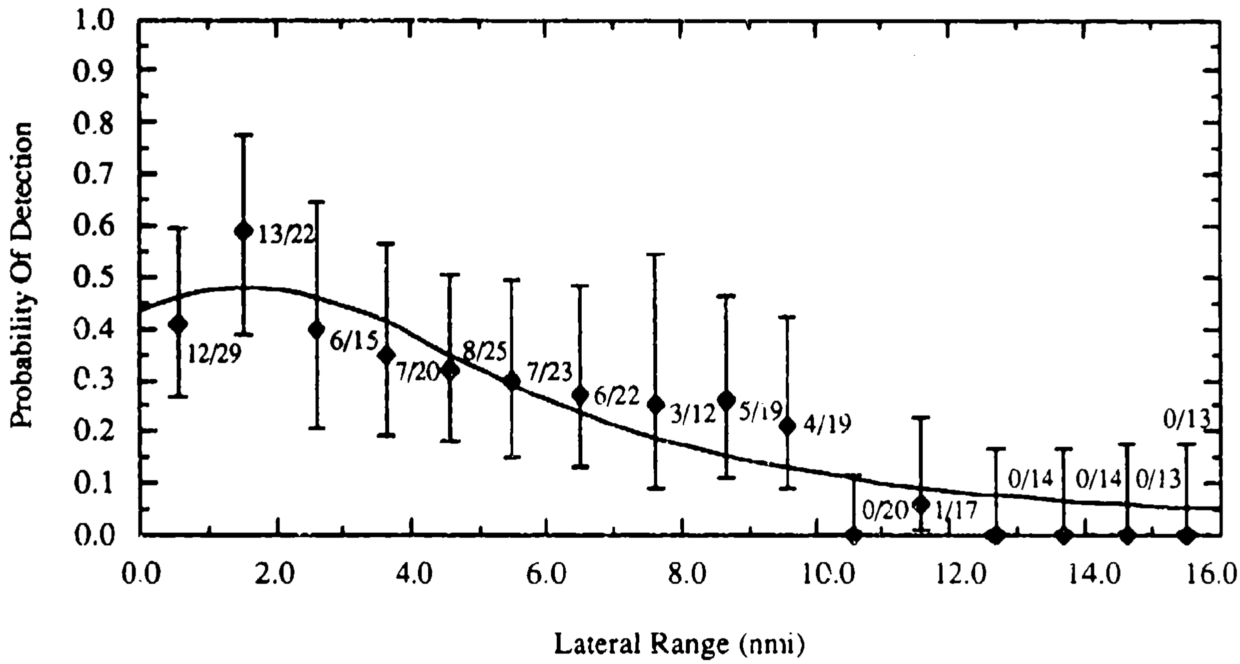

Figure 2-3. AN/APS-137 FLAR Detection of Life Rafts (2.5 ft < $H_S \leq 3.6$ ft)

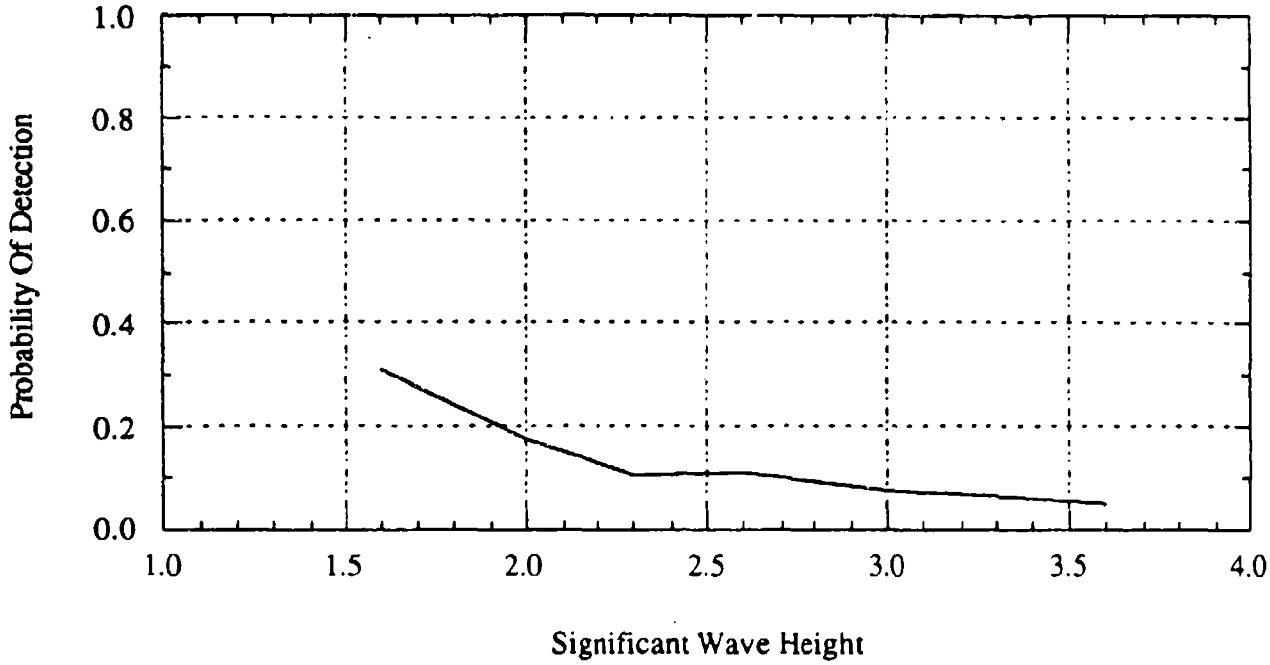

Figure 2-4. The Effect of Significant Wave Height on Detection of Life Rafts

The difference of only 1.6 nmi is due in part to the relatively close mean values for H_S for each data set (2.1 feet and 2.9 feet, respectively) and also to the generally low probability of detection over the entire range scale.

2.2.2 Comparison of Detection Performance of the AN/APS-137 FLAR to the AN/APS-127 FLAR

AN/APS-137 FLAR data for life-raft detections were compared to the corresponding data collected for the AN/APS-127 FLAR (reference 6). No sweep widths were generated for the AN/APS-127 FLAR for life-raft detection due to the relatively small data set; however, a general qualitative comparison was conducted. In order to compare the two radar capabilities, the AN/APS-137 FLAR data set was separated into two data subsets for H_S less than 2 feet and H_S between 2 and 3.6 feet. This criteria corresponded to the AN/APS-127 FLAR data grouping.

Figures 2-5 through 2-8 show the results of the comparison. For both data subsets, the AN/APS-137 FLAR showed a considerable improvement over the AN/APS-127 FLAR. This difference existed out to approximately 12 nmi for the lower sea conditions and out to the edge of the AN/APS-137 FLAR range scale for the higher sea conditions.

A pairwise comparison of the detection capabilities for the lateral range bins shows the AN/APS-137 FLAR to perform better than the AN/APS-127 FLAR over all lateral range bins except those from 14 to 16 nmi. The reason for this is probably due to the slight difference in range scales of the two radars. Targets on the very edge of the 16 nmi range scale for the AN/APS-137 FLAR were 4 to 6 nmi from the edge of the 20 nmi range scale of the AN/APS-127 FLAR. This gives the operator of the AN/APS-127 FLAR more opportunities to see a weak contact. Range scales larger than 20 nmi, however, may eventually reach a point where the resolution degrades enough to decrease detectability. Direct comparison of the two radars at lateral ranges near the edge of one of the range scales should be avoided.

2.3 HUMAN FACTORS

The search parameters and general crew comments were analyzed for search conditions that significantly affect the operator's ability to detect a valid target. The search parameter that was analyzed for its direct effect on the operator was time-on-task. Crew and observer comments were also recorded and reviewed and the results presented.

2.3.1 Detection Performance Versus Time-on-Task

Time-on-task was not a significant variable for any of the searches or any of the targets. However, the LOGIT analysis and Pearson correlation analysis (using SYSTAT) showed time-on-task to be slightly correlated with windspeed and H_S. The effects of time-on-task could not be effectively isolated from the other search parameters and should be evaluated again in future tests.

It was generally observed that the crew remained alert for the duration of the search. The radar operators were relieved by fresh operators at 1- to 1.5-hour intervals or as necessary. While this procedure ensured alert operators for optimum detection performance, it did not allow for an effective analysis of the time-on-task for an operator on the scope. Future tests should consider leaving the operator on the scope for longer periods.

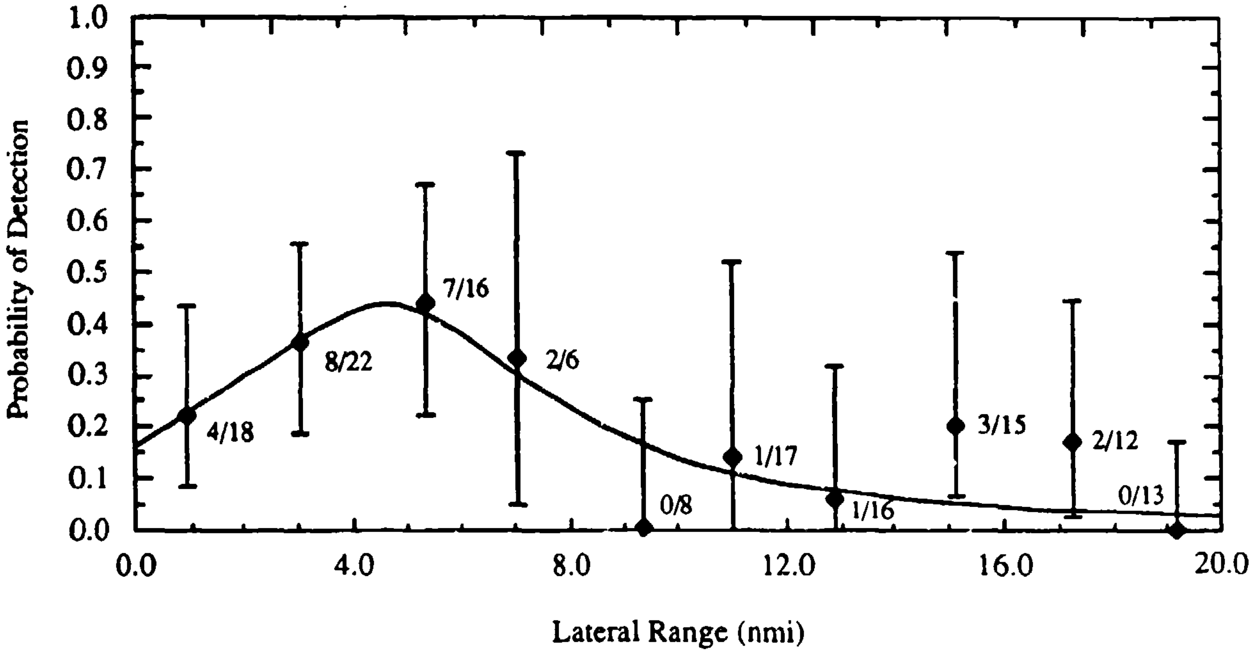

Figure 2-5. AN/APS-127 FLAR Detection of Life Rafts ($H_S \leq 2.0$ ft)

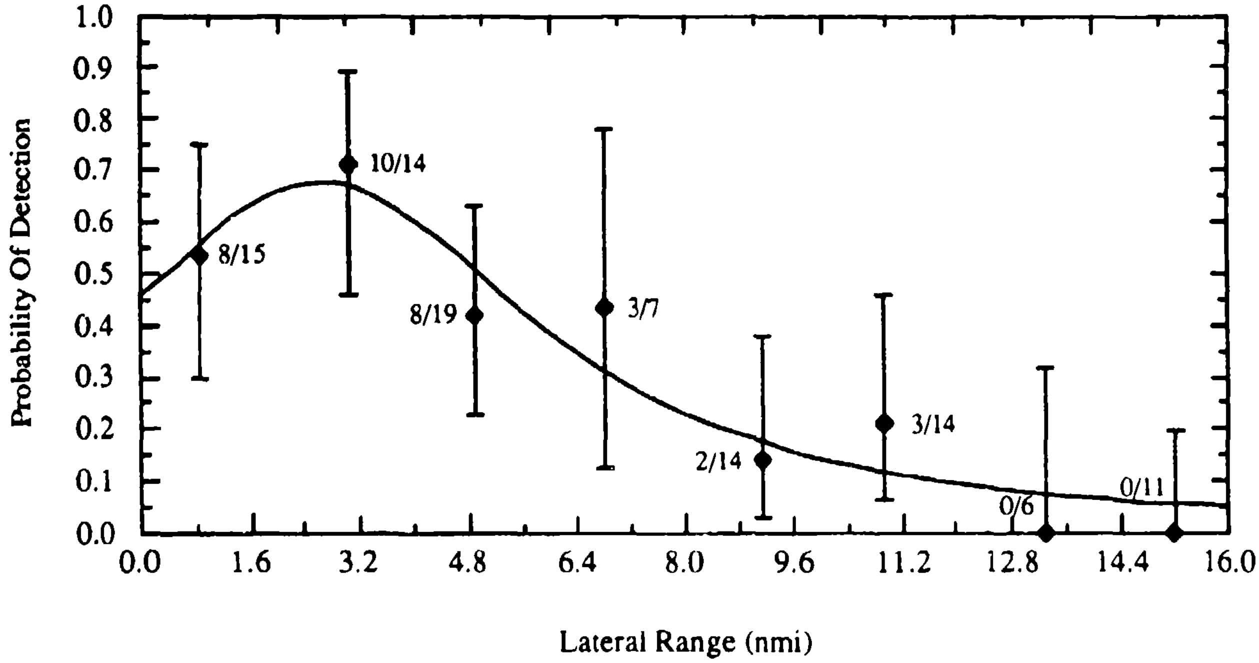

Figure 2-6. AN/APS-137 FLAR Detection of Life Rafts ($H_S \leq 2.0$ ft)

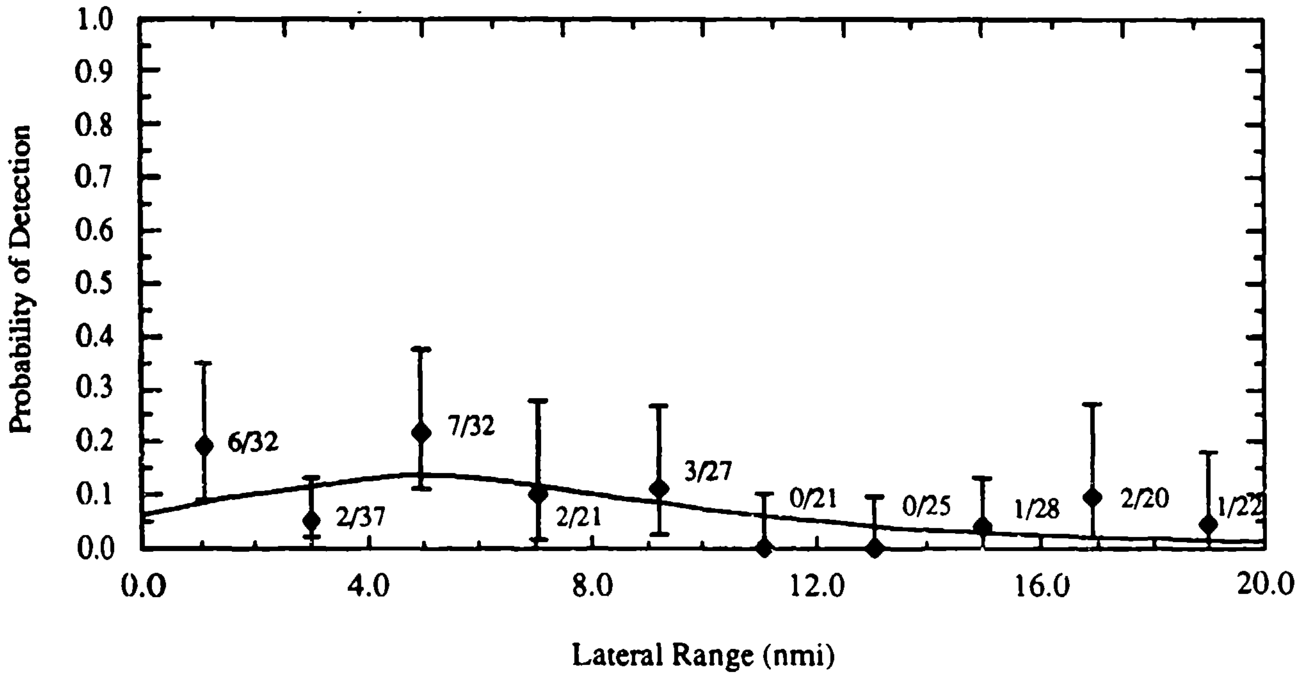

Figure 2-7. AN/APS-127 FLAR Detection of Life Rafts (2.0 ft < $H_S \leq$ 3.9 ft)

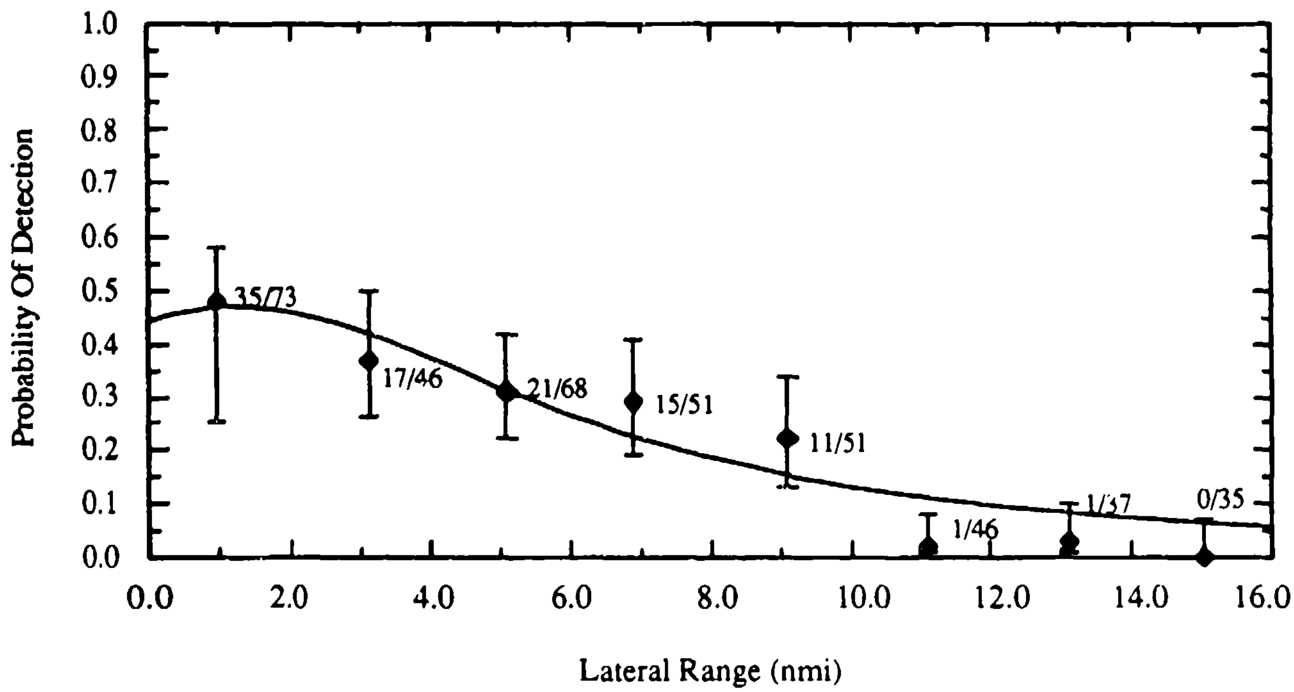

Figure 2-8. AN/APS-137 FLAR Detection of Life Rafts (2.0 ft < $H_S \leq$ 3.6 ft)

2.3.2 Detection Performance Versus Relative Bearing

Figure 2-9 shows the polar plot of the frequency of detection occurrence of life rafts versus the relative bearing from the aircraft. The data points are plotted with a cubic spline interpolation curve. There are not enough detections of small boats to give an accurate representation of the detection response by relative bearing.

A significantly large percentage of raft detections were made directly in front of the aircraft (the 12 o'clock position); even though the targets at ± 30° relative to the aircraft spent the longest time on the screen. The slight asymetry seen between the left and right side of the aircraft may have been due to the size of the detection data set. Though some operators tended to search toward one side of the aircraft, no difference between sides is expected given a sufficient variety of radar operators. The absence of detections behind the aircraft is due to the radar baffled area and is a characteristic of nose-mounted radars.

2.3.3 Crew Comments

The following is a summary of comments made by the crew during the searches and during the crew debrief, held after each search.

- 240 knots is too fast to do an effective search for small targets. A better speed is between 180 and 200 knots.
- Some operators thought they could see a raft out to about 4 nmi, others out to the end of the range scale.
- Each operator thought they needed to "warm up" on the way out to the search area by using visually identified targets of opportunity.
- Operators complained about losing contacts at about 5 nmi then regaining the same target again at about 1 nmi. They thought that having the radar in manual tilt control would solve this problem. (Manual tilt control would normally be used for investigating a specific target.)

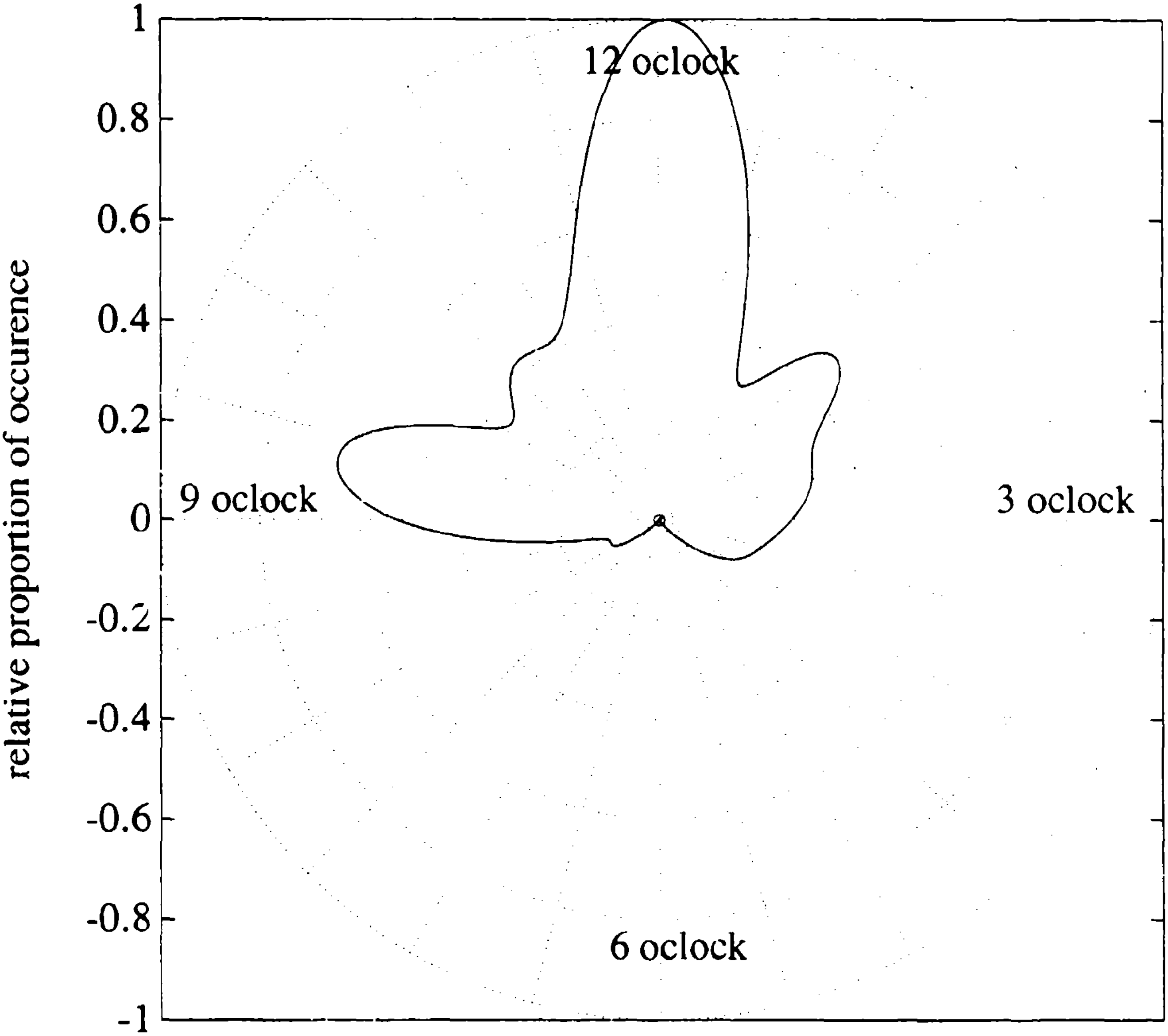

Figure 2-9. AN/APS-137 FLAR Detection Performance of Life Rafts versus Relative Bearing

In general, the operators were only able to distinguish small-boat contacts from larger ships and, at times, were able to distinguish water surface anomalies (i.e., wakes, schools of fish) from vessel traffic.

2.3.4 Data Recorder/Observer Comments

The following is a summary of the comments recorded by the test team personnel who were on the aircraft during the search.

- Within 15 nmi of shore, the vessel traffic was very heavy, and the operator was fully occupied with tagging every contact. Faint or intermittent targets may have been missed.

- Some of the operators did not believe that they could distinguish a life raft from a small boat, while others were fairly confident in their ability to classify certain contacts by the PPI display alone. To the observers, it did not appear that an operator could consistently identify types of vessel targets by the PPI display alone beyond differentiating between large (merchants, oilers, etc.) and small (small boats, life rafts) targets.

- Radar operator procedures varied significantly from operator to operator. Search procedures and tagging procedures were largely based on personal preferences and, in some cases, may have been due to the operator's perception of his role in a test scenario rather than a search. Variations included, but were not limited to, the following:

  - Use of B-Scan,
  - Use of BKGD or THRS mode (video process),
  - Auto or Manual Tilt Control,
  - Area (on the screen) or concentration of the search, and
  - Target-sea return discrimination.

- Some radar operators did not understand why they should search further out than the track spacing.

- The new 14-inch radar display on the AN/APS-137 FLAR Palletized Radar Operator's Station (PROS) pallet was clear and appeared to reduce eyestrain previously experienced with the 9-inch PPI display.

2.3.5 Data Reconstruction Observations

The following is a summary of observations made during the data reconstruction.

- The INS error did not appear to be constant after a course change. If the INS error had a significant cross-track component, then it is possible that the distance between two successive legs could be significantly larger than the recommended value and full search area coverage not attained.

- Operators appeared to concentrate much of their search within about one track spacing distance from the aircraft.

- Weak contacts at very small CPAs were easily obscured by the aircraft heading cursor on the PPI display. At 200 knots, the heading cursor moves sufficiently fast enough across the screen that the cursor quickly hides close CPA contacts. The cursor also hides close aboard weak contacts that cannot be detected beyond the length of the cursor.

- Radar operators tended to wait to refresh the screen until approximately half of the display was off the screen This equates to about 2 minutes between each screen refresh. It requires about 5 to 10 seconds for each screen to be functional after a refresh. The delay in refreshing the screen appeared to be at least partly responsible for several misses of weak targets with limited on-screen time.

CHAPTER 3
CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

Based on the analyses presented in Chapter 2, the following conclusions are drawn concerning the AN/APS-137 FLAR performance.

3.1.1 AN/APS-137 FLAR Dete..ion Performance for Life Rafts

1. The significant variables for AN/APS-137 FLAR detection performance against life-raft targets are lateral range and significant wave height (H_S). As expected, lateral range was the dominant variable in determining the probability of detection in all sea conditions. The detection performance decreased steadily as H_S increased up to about 2.5 feet. The overall detection probability for H_S greater than 2.5 feet leveled off at less than 0.1, and increasing H_S up to at least 3.6 feet had little effect on detection probability.

2. The detection data were grouped using 2.0 feet as the H_S criteria to compare the AN/APS-137 FLAR performance to that of the AN/APS-127 FLAR. The AN/APS-137 FLAR performed at least 50 percent better than the AN/APS-127 FLAR out to about 4 nmi for the lower H_S condition and out to about 12 nmi for the higher H_S condition. Beyond these ranges, the performances of the two FLAR systems were approximately equal against life-raft targets.

3. The life-raft detection data for both the AN/APS-137 FLAR and the AN/APS-127 FLAR show a notable decrease in radar detection performance for H_S conditions above 2 to 3 feet while searching at 1500 feet. It could not be determined from the data whether searching at a lower altitude would significantly increase detection performance for higher H_S conditions.

4. The AN/APS-127 FLAR, on the 20 nmi range scale, displayed a slight ability to detect life rafts at long ranges for H_S conditions less than 2 feet. The marginal difference between the AN/APS-137 FLAR and the AN/APS-127 FLAR at or near 16 nmi is most

likely due to the difference in range scales. Given the observed performance against life-raft targets, it is reasonable to expect the AN/APS-137 FLAR to perform at least as well as the AN/APS-127 FLAR for the same PPI display.

5. The standard search and rescue practice of visually verifying every radar contact may be difficult in areas of even moderate target density. Diversions from the established track line decrease search efficiency.

3.1.2 General Conclusions

1. The derivation of sweep width is based on the assumption that the operator is able to conduct a search out to the search horizon (i.e., edge of the range scale). A searcher/radar operator should not restrict the search to only a portion of the radar display when the track spacing is less than the maximum range on the radar display. The calculated sweep width is based on the assumption that there will be both missed detections in close (at ranges less than 1/2 sweep width) and detections near the edge of the radar display (at ranges greater than 1/2 sweep width). The operator should not assume that a target that could be detected on the current search leg would be detected on the next search leg. The radar operator should always search out to the edge of the range scale (and not be limited by track spacing) so that opportunities to detect a target are not missed.

2. The 14-inch PROS pallet display is an improvement over the previous 9-inch display. The display is easy to read and produces less eyestrain over a prolonged search.

3.2 RECOMMENDATIONS

The following recommendations are made concerning airborne search planning using the AN/APS-137 FLAR.

3.2.1 AN/APS-137 FLAR Search for Life Rafts

1. The sweep widths provided in table 3-1 should be used for all AN/APS-137 FLAR searches for life rafts.

Table 3-1. Sweep Widths for 4-, 6-, and 10-Person Life Rafts Using the AN/APS-137 FLAR

Range Scale (nmi)	Significant Wave Height (feet)	Sweep Width (nmi)
16	≤ 2.5	9
	2.5 to 3.6	7

2. Although search data at different range scales is not available for this report, based on the Spring 1992 data, it is recommended that the 16-nmi range scale in Periscope Mode be used while searching for rafts in seas from 1.6 to 3.6 feet. From 8 to 12 nmi there is a sufficiently high probability of detection to use a range scale higher than 8. The probability of detection falls to near-zero beyond 14 nmi, and it is likely that the 32-nmi range scale is too large for life-raft targets and may, in fact, degrade performance due to the smaller screen resolution. In a very narrow search area, the 16-nmi range scale allows for a longer visual integration time than the 8-nmi range scale and less required-refreshing of the screen in the Ground Stabilized Mode.

3.2.2 General Recommendations

1. The AN/APS-137 FLAR operator should reposition the sweep origin at approximately 1 minute intervals when searching in the Ground Stabilized Mode. This practice will maximize the on-screen time for weak contacts and for those contacts that pass close aboard. Weak and close-aboard contacts may only appear briefly before they are lost in the increasing sea clutter or the fuselage shadow, and maximizing the amount of uninterrupted time that the operator can observe the screen will improve the probability of detecting these targets.

2. For weak targets, the lower surface clutter at longer ranges may actually enhance detectability under certain environmental conditions. Also, the joint probability of detection for multiple legs significantly increases the total probability of detection, even for marginally detectable targets. Radar operators should not concentrate all of their efforts to within one track spacing but should look out to reasonable ranges beyond. For rafts in seas up to 3.6 feet, this range should be no less than 12 nmi.

3. When conducting searches for weak or small targets, the operator should turn the heading cursor off. Leaving the cursor on may actually hide close-aboard, weak targets.

3.2.3 Recommendations for Future Research

1. The small-boat data from the Spring 1992 test is very scarce, and it is not clear whether the data validly represent AN/APS-137 FLAR small-boat detection capabilities. Furthermore, the test only used small boats from 37 to 56 feet in length. Data are needed for small boats of all sizes, but especially in the 20- to 37-foot range. Any future test should contain these target types.

2. The data set for life rafts in seas of less than 2 feet is small, and further tests should be conducted for life rafts in small H_S conditions to enhance this data set.

3. Since the operators rotated regularly throughout each search, it was not possible to analyze the real affect of time-on-task on the operator. Future tests should consider leaving an operator on the radar for an extended period of time to investigate the effects of fatigue.

4. When searching in moderate contact density for small contacts that cannot be visually identified from the airborne SRU trackline, the SRU should, if possible, minimize the number of deviations from the search track to visually identify the target. Some alternate method of identification (chase plane, etc.) should be used, if available.

5. Future tests should include data to determine the effects of altitude on detection performance under various environmental conditions.

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APPENDIX A
SPRING 1992 DATA

KEY TO DATA APPENDIX

This appendix contains the raw data files for the U.S. Coast Guard AN/APS-137 Forward Looking Airborne Radar experiment conducted in the Spring of 1992. Each data file is labeled with the date on which the data were collected.

The data files are listed in chronological order. Each file record represents one search unit/target interaction and describes the target detection opportunity using 14 parameters of interest. The following is a key to the format of each record.

Item 1:	DET	Detection? (1 = yes, 2 = no)
Item 2:	TOT	Time on task (hours)
Item 3:	RNG	The aircraft reported range
Item 4:	LATRNG	Lateral range (nautical miles)
Item 5:	RNGSC	Range scale 0 = 8-nautical miles, 1 = 16-nautical miles, 2 = 32-nautical miles
Item 6:	RBg	Relative Bearing of the target from the aircraft (degrees)
Item 7:	ALT	Aircraft altitude (feet)
Item 8:	WDSP	Wind speed (knots)
Item 9:	SWDIR	Relative wave direction 1 = looking into oncoming waves, 0 = looking across the direction of wave travel, -1 = looking at the backside of the waves
Item 10:	HS	Significant wave height (feet)
Item 11:	PRECIP	Precipitation level ( ) = none, 1 = light, 2 = moderate, 3 = heavy)
Item 12:	WCAPS	Whitecap coverage (0 = none, 1 = light, 2 = heavy)
Item 13:	SIZE	The size of the target (feet) rafts = outside diameter boats = overall length
Item 14:	TGTREF	Type of target rafts = 0 rafts with reflector = 1 boats wood = 2 fiberglass = 3 metal = 4

March 30, 1992

DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	0.5	9.9	9.9	1	092	1500	7.6	0	1.6	0	0	6	0
1	0.6	7.4	7.0	1	112	1500	7.6	1	1.6	0	0	10	0
1	0.7	6.0	1.5	1	345	1500	7.6	1	1.6	0	0	10	0
1	0.7	2.1	0.4	1	010	1500	7.6	-1	1.6	0	0	10	0
1	1.0	3.0	2.8	1	077	1500	6.0	0	3.0	0	0	10	0
1	1.2	4.1	1.1	1	016	1500	6.0	-1	3.0	0	0	6	0
1	1.3	7.1	6.9	1	079	1500	6.0	-1	3.0	0	0	10	0
1	1.4	0.7	0.2	1	000	1500	6.0	-1	3.0	0	0	4	0
1	1.5	3.8	3.8	1	080	1500	7.4	0	1.6	0	0	6	0
1	1.5	5.0	4.9	1	259	1500	6.0	0	3.0	0	0	6	0
1	1.8	5.4	0.1	1	003	1500	7.6	-1	1.6	0	0	6	0
1	1.9	3.1	3.0	1	230	1500	7.6	0	1.6	0	0	10	0
1	2.0	8.3	8.2	1	092	1500	7.6	0	1.6	0	0	6	0
1	2.1	7.1	6.2	1	310	1500	7.6	1	1.6	0	0	10	0
1	2.3	6.3	3.6	1	034	1500	5.2	-1	3.0	0	0	6	0
1	2.4	6.1	4.6	1	310	1500	5.2	1	3.0	0	0	6	0
1	2.4	6.0	2.0	1	020	1500	5.2	1	3.0	0	0	6	0
1	2.6	3.6	0.2	1	000	1500	5.2	1	3.0	0	0	6	0
1	2.7	11.2	9.2	1	056	1500	5.2	-1	3.0	0	0	41	3
1	2.7	2.9	2.8	1	243	1500	5.2	1	3.0	0	0	10	0
1	2.8	9.3	4.8	1	332	1500	5.2	0	3.0	0	0	6	0
1	2.9	9.3	8.9	1	104	1500	6.4	0	3.0	0	0	10	0
1	2.9	4.1	4.1	1	097	1500	6.4	0	3.0	0	0	10	0
1	3.0	3.6	3.6	1	095	1500	6.4	0	3.0	0	0	10	0
1	3.4	3.6	2.2	1	322	1500	7.0	-1	2.0	0	1	6	0
1	3.4	5.6	5.5	1	082	1500	7.0	0	2.0	0	1	10	0
1	3.5	12.4	9.9	1	307	1500	7.0	1	2.0	0	1	52	3
1	3.5	2.4	2.3	1	072	1500	7.0	0	2.0	0	1	10	0
1	3.5	2.0	0.1	1	000	1500	7.0	1	2.0	1	1	6	0
1	3.7	8.4	5.3	1	039	1500	7.6	1	3.0	0	0	6	0
1	3.8	7.5	2.7	1	016	1500	7.6	1	3.0	0	0	10	0
1	3.8	8.8	4.9	1	326	1500	7.6	1	3.0	0	0	37	4
1	3.9	5.3	0.9	1	009	1500	7.8	1	3.0	0	0	10	0
1	3.9	11.8	3.8	1	341	1500	7.8	0	2.6	0	0	10	0
1	3.9	9.6	9.0	1	290	1500	7.8	0	2.6	0	0	4	0
1	4.0	8.2	4.4	1	328	1500	7.8	0	2.6	0	0	41	3
1	4.0	3.1	3.0	1	284	1500	7.8	-1	2.6	0	0	6	0
1	4.0	7.6	7.5	1	098	1500	7.8	0	2.6	0	0	10	0
1	4.1	3.0	0.6	1	011	1500	7.8	0	2.6	0	0	41	3
1	4.1	2.0	1.5	1	133	1500	7.8	0	2.6	0	0	6	0
1	4.2	12.7	2.3	1	011	1500	7.8	-1	2.6	0	0	45	3
1	4.2	4.3	4.1	1	252	1500	7.8	1	2.6	0	0	4	0
1	4.3	10.9	0.1	1	002	1500	9.7	-1	2.6	0	0	37	4
1	4.6	9.1	2.2	1	014	1500	6.8	-1	1.6	0	0	10	0
1	4.7	7.6	3.7	1	029	1500	6.8	-1	1.6	0	0	52	3
1	4.7	5.0	5.0	1	268	1500	6.8	0	1.6	0	0	6	0
1	4.8	12.9	6.5	1	030	1500	6.8	-1	1.6	0	0	56	3
1	4.8	6.1	1.5	1	014	1500	7.2	1	1.6	0	0	52	3
1	5.1	5.2	4.7	1	064	1500	9.9	1	2.6	0	0	6	0
1	5.3	11.2	2.7	1	014	1500	9.9	1	2.6	0	0	45	3
1	5.3	8.2	0.1	1	000	1500	9.9	1	2.6	0	0	4	0
1	5.3	14.5	4.2	1	017	1500	8.6	1	2.6	0	0	41	3
1	1.2	6.1	6.1	1	087	1500	6.0	1	3.0	0	0	6	0
1	1.6	2.4	2.4	1	082	1500	6.0	0	3.0	0	0	6	0
1	2.2	6.2	5.5	1	063	1500	7.6	0	1.6	0	0	6	0
1	2.4	9.3	7.9	1	302	1500	5.2	1	3.0	0	0	10	0
1	2.8	13.4	12.4	1	068	1500	6.4	-1	3.0	0	0	45	3

March 30, 1992

DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	3.3	15.4	14.8	1	073	1500	6.8	0	2.0	0	1	52	3
1	3.3	10.7	10.6	1	263	1500	6.8	0	2.0	0	1	6	0
1	3.9	14.1	6.4	1	333	1500	7.8	0	3.0	0	0	45	3
2	0.1	11.2	11.2	1	090	1500	4.9	-1	2.6	0	0	4	0
2	0.1	4.5	4.5	1	090	1500	4.9	-1	2.6	0	0	6	0
2	0.1	0.6	0.6	1	270	1500	4.9	1	2.6	0	0	6	0
2	0.1	15.1	15.1	1	090	1500	4.9	-1	2.6	0	0	6	0
2	0.2	10.3	10.3	1	090	1500	4.9	-1	2.6	0	0	4	0
2	0.3	4.9	4.9	1	090	1500	4.9	0	2.6	0	0	6	0
2	0.3	13.5	13.5	1	090	1500	4.9	0	2.6	0	0	6	0
2	0.3	2.9	2.9	1	090	1500	5.4	0	2.6	0	0	10	0
2	0.4	12.0	12.0	1	090	1500	5.4	0	2.6	0	0	6	0
2	0.6	5.3	5.3	1	090	1500	7.6	0	1.6	0	0	10	0
2	0.6	1.1	1.1	1	090	1500	7.6	0	1.6	0	0	10	0
2	0.7	4.2	4.2	1	090	1500	7.6	0	1.6	0	0	10	0
2	0.7	12.9	12.9	1	270	1500	7.6	0	1.6	0	0	6	0
2	0.8	4.2	4.2	1	270	1500	7.6	0	1.6	0	0	6	0
2	0.9	14.4	14.4	1	270	1500	6.0	0	3.0	0	0	6	0
2	1.0	6.1	6.1	1	270	1500	6.0	0	3.0	0	0	6	0
2	1.0	7.6	7.6	1	270	1500	6.0	0	3.0	0	0	6	0
2	1.0	14.1	14.1	1	270	1500	6.0	0	3.0	0	0	10	0
2	1.0	0.9	0.9	1	090	1500	6.0	0	3.0	0	0	6	0
2	1.1	4.6	4.6	1	270	1500	6.0	-1	3.0	0	0	4	0
2	1.2	9.4	9.4	1	270	1500	6.0	-1	3.0	0	0	6	0
2	1.2	11.8	11.8	1	270	1500	6.0	-1	3.0	0	0	10	0
2	1.2	5.8	5.8	1	270	1500	6.0	-1	3.0	0	0	4	0
2	1.3	1.0	1.0	1	090	1500	6.0	1	3.0	0	0	4	0
2	1.3	5.5	5.5	1	270	1500	6.0	-1	3.0	0	0	6	0
2	1.4	10.5	10.5	1	270	1500	6.0	-1	3.0	0	0	6	0
2	1.5	14.0	14.0	1	090	1500	6.0	0	3.0	0	0	10	0
2	1.5	10.2	10.2	1	090	1500	6.0	0	3.0	0	0	10	0
2	1.6	13.6	13.6	1	090	1500	6.0	0	3.0	0	0	10	0
2	1.6	6.8	6.8	1	270	1500	6.0	0	3.0	0	0	10	0
2	1.6	10.5	10.5	1	090	1500	6.0	0	3.0	0	0	6	0
2	1.9	11.6	11.6	1	090	1500	7.6	0	1.6	0	0	10	0
2	1.9	4.7	4.7	1	270	1500	7.6	0	1.6	0	0	10	0
2	1.9	15.6	15.6	1	090	1500	7.6	0	1.6	0	0	10	0
2	1.9	9.0	9.0	1	270	1500	7.6	0	1.6	0	0	10	0
2	2.1	8.4	8.4	1	090	1500	7.6	0	1.6	0	0	10	0
2	2.1	10.2	10.2	1	090	1500	7.6	0	1.6	0	0	10	0
2	2.2	11.0	11.0	1	270	1500	7.6	0	1.6	0	0	6	0
2	2.4	12.8	12.8	1	090	1500	5.2	0	3.0	0	0	10	0
2	2.4	15.4	15.4	1	270	1500	5.2	0	3.0	0	0	6	0
2	2.4	15.5	15.5	1	270	1500	5.2	0	3.0	0	0	37	4
2	2.4	4.2	4.2	1	270	1500	5.2	0	3.0	0	0	10	0
2	2.4	10.8	10.8	1	090	1500	5.2	0	3.0	0	0	6	0
2	2.5	8.6	8.6	1	270	1500	5.2	0	3.0	0	0	10	0
2	2.5	5.1	5.1	1	090	1500	5.2	1	3.0	0	0	4	0
2	2.5	13.8	13.8	1	270	1500	5.2	-1	3.0	0	0	10	0
2	2.6	15.8	15.8	1	090	1500	5.2	1	3.0	0	0	6	0

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DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	0.1	18.3	14.4	1	051	1000	5.6	1	2.3	0	0	54	3
1	0.3	3.9	3.2	1	054	1000	8.0	1	2.3	0	0	10	0
1	0.3	6.1	1.2	1	349	1000	8.0	-1	2.3	0	0	10	0
1	0.6	11.7	11.1	1	097	1000	2.9	1	3.0	0	0	10	0
1	1.1	7.2	2.0	1	016	1000	7.4	0	2.3	0	0	10	0
1	1.5	3.9	2.6	1	041	1000	7.6	1	2.3	0	0	6	0
1	1.7	7.0	0.6	1	355	1000	7.6	0	2.3	0	0	6	0
1	1.8	7.6	0.9	1	353	1000	7.6	0	2.3	0	0	6	0
1	2.0	5.7	1.3	1	013	1000	7.0	-1	3.0	0	0	10	0
1	2.1	4.9	0.4	1	004	1000	7.0	-1	3.0	0	0	10	0
1	2.2	8.2	3.5	1	025	1000	4.7	0	3.0	0	0	10	0
1	2.7	0.7	0.3	1	024	1000	7.8	0	2.3	0	0	10	0
1	3.6	9.7	9.2	1	252	1000	6.4	0	3.0	0	0	56	3
1	3.7	15.9	15.8	1	276	1000	6.2	1	3.0	0	0	52	3
1	3.7	4.6	4.6	1	278	1000	6.2	1	3.0	0	0	10	0
1	4.0	11.1	5.0	1	333	1000	5.2	1	2.0	0	1	6	0
1	4.0	14.6	5.5	1	338	1000	5.2	1	2.0	0	1	54	3
1	4.0	3.5	3.5	1	085	1000	5.2	-1	2.0	0	1	6	0
1	4.2	5.0	0.6	1	353	1000	4.5	0	2.0	0	1	4	0
1	4.3	2.7	0.6	1	012	1000	4.5	0	2.0	0	1	4	0
1	4.3	7.6	3.2	1	335	1000	4.5	0	2.0	0	1	10	0
1	4.5	4.4	4.0	1	290	1000	4.5	-1	2.0	0	1	4	0
1	4.6	8.4	7.2	1	301	1000	4.5	-1	2.0	0	1	6	0
1	5.0	7.1	0.4	1	357	1000	3.7	-1	2.6	0	0	10	0
1	5.0	10.0	8.5	1	059	1000	3.7	0	2.6	0	0	10	0
1	5.0	8.9	5.5	1	322	1000	3.7	-1	2.6	0	0	10	0
1	5.2	4.6	4.3	1	110	1000	3.7	-1	2.6	0	0	10	0
1	5.2	3.9	3.2	1	055	1000	3.9	0	2.6	0	0	10	0
1	5.2	5.0	3.5	1	316	1000	3.9	1	2.6	0	0	6	0
1	4.0	11.7	4.4	1	338	1000	5.2	0	2.0	0	1	37	4
1	4.3	8.1	5.2	1	320	1000	4.5	0	2.0	0	1	41	3
2	0.1	13.2	13.2	1	090	1000	5.6	1	2.3	0	0	6	0
2	0.1	5.4	5.4	1	090	1000	5.6	1	2.3	0	0	10	0
2	0.1	1.1	1.1	1	270	1000	5.6	-1	2.3	0	0	10	0
2	0.2	10.0	10.0	1	090	1000	7.8	1	2.3	0	0	6	0
2	0.3	9.2	9.2	1	090	1000	7.8	1	2.3	0	0	6	0
2	0.6	5.0	5.0	1	090	1000	2.9	1	3.0	0	0	6	0
2	0.7	2.5	2.5	1	090	1000	5.6	1	3.0	0	0	10	0
2	0.7	9.8	9.8	1	270	1000	5.6	1	3.0	0	0	10	0
2	0.8	0.0	0.0	1	000	1000	5.6	0	3.0	0	0	6	0
2	0.8	6.2	6.2	1	270	1000	5.6	1	3.0	0	0	10	0
2	0.8	13.0	13.0	1	270	1000	5.6	1	3.0	0	0	6	0
2	1.1	4.2	4.2	1	270	1000	7.4	1	2.3	0	0	6	0
2	1.1	6.4	6.4	1	090	1000	7.4	-1	2.3	0	0	10	0
2	1.2	4.4	4.4	1	270	1000	7.6	1	2.3	0	0	6	0
2	1.2	8.8	8.8	1	270	1000	7.6	1	2.3	0	0	10	0
2	1.3	3.9	3.9	1	270	1000	7.6	1	2.3	0	0	10	0
2	1.3	6.9	6.9	1	090	1000	7.6	-1	2.3	0	0	10	0
2	1.3	0.5	0.5	1	090	1000	7.6	-1	2.3	0	0	10	0
2	1.3	7.5	7.5	1	270	1000	7.6	1	2.3	0	0	6	0
2	1.5	5.2	5.2	1	270	1000	7.6	-1	2.3	0	0	10	0
2	1.6	1.0	1.0	1	270	1000	7.6	-1	2.3	0	0	10	0
2	1.6	11.6	11.6	1	270	1000	7.6	-1	2.3	0	0	10	0
2	1.7	4.2	4.2	1	090	1000	7.6	1	2.3	0	0	10	0
2	1.7	7.0	7.0	1	270	1000	7.6	-1	2.3	0	0	10	0
2	1.7	11.2	11.2	1	270	1000	7.6	-1	2.3	0	0	10	0
2	1.7	5.6	5.6	1	090	1000	7.6	1	2.3	0	0	6	0

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DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	2.0	7.8	7.8	1	090	1000	7.0	1	3.0	0	0	6	0
2	2.1	4.8	4.8	1	270	1000	7.0	-1	3.0	0	0	6	0
2	2.1	14.0	14.0	1	090	1000	7.0	1	3.0	0	0	10	0
2	2.1	7.2	7.2	1	090	1000	7.0	1	3.0	0	0	10	0
2	2.2	12.0	12.0	1	090	1000	4.7	1	3.0	0	0	10	0
2	2.2	4.6	4.6	1	090	1000	4.7	-1	3.0	0	0	10	0
2	2.2	8.8	8.8	1	270	1000	4.7	1	3.0	0	0	10	0
2	2.2	14.2	14.2	1	270	1000	4.7	1	3.0	0	0	10	0
2	2.2	9.8	9.8	1	090	1000	4.7	-1	3.0	0	0	6	0
2	2.3	2.8	2.8	1	270	1000	4.7	1	3.0	0	0	6	0
2	2.5	6.1	6.1	1	090	1000	8.9	-1	2.3	0	0	6	0
2	2.6	0.1	0.1	1	270	1000	8.9	1	2.3	0	0	6	0
2	2.6	8.2	8.2	1	270	1000	8.9	1	2.3	0	0	6	0
2	2.6	15.8	15.8	1	270	1000	8.9	1	2.3	0	0	6	0
2	2.6	12.2	12.2	1	090	1000	8.9	-1	2.3	0	0	10	0
2	2.6	5.5	5.5	1	090	1000	8.9	-1	2.3	0	0	6	0
2	2.7	7.8	7.8	1	270	1000	7.8	1	2.3	0	0	10	0
2	2.7	6.0	6.0	1	090	1000	7.8	-1	2.3	0	0	10	0
2	2.8	8.1	8.1	1	270	1000	7.8	1	2.3	0	0	45	3
2	2.8	1.2	1.2	1	090	1000	7.8	-1	2.3	0	0	6	0
2	2.8	9.9	9.9	1	090	1000	7.8	-1	2.3	0	0	10	0
2	2.8	2.2	2.2	1	090	1000	7.8	-1	2.3	0	0	6	0
2	2.8	11.7	11.7	1	270	1000	7.8	1	2.3	0	0	4	0
2	2.8	2.1	2.1	1	270	1000	7.8	1	2.3	0	0	4	0
2	3.6	0.7	0.7	1	090	1000	6.4	0	3.0	0	0	10	0
2	3.7	13.5	13.5	1	270	1000	6.2	0	3.0	0	0	10	0
2	3.7	13.3	13.3	1	090	1000	6.2	0	3.0	0	0	10	0
2	3.7	6.6	6.6	1	090	1000	6.2	-1	3.0	0	0	6	0
2	4.0	11.6	11.6	1	090	1000	5.2	-1	2.0	0	1	6	0
2	4.1	5.5	5.5	1	270	1000	5.2	1	2.0	0	1	4	0
2	4.2	4.6	4.6	1	090	1000	5.2	-1	2.0	0	1	10	0
2	4.2	13.4	13.4	1	090	1000	5.2	-1	2.0	0	1	10	0
2	4.3	13.8	13.8	1	090	1000	4.5	-1	2.0	0	1	6	0
2	4.3	14.5	14.5	1	090	1000	4.5	-1	2.0	0	1	6	0
2	4.3	10.5	10.5	1	090	1000	4.5	-1	2.0	0	1	4	0
2	4.4	15.2	15.2	1	270	1000	4.5	-1	2.0	0	1	4	0
2	4.4	5.5	5.5	1	270	1000	4.5	-1	2.0	0	1	4	0
2	4.6	8.5	8.5	1	270	1000	4.5	-1	2.0	0	1	10	0
2	4.6	1.7	1.7	1	090	1000	4.5	1	2.0	0	1	4	0
2	4.6	0.9	0.9	1	090	1000	4.5	1	2.0	0	1	54	3
2	4.7	0.6	0.6	1	090	1000	4.7	1	2.0	0	1	6	0
2	4.7	15.2	15.2	1	270	1000	4.7	-1	2.0	0	1	6	0
2	4.7	0.8	0.8	1	090	1000	4.7	1	2.0	0	1	37	4
2	5.0	11.2	11.2	1	270	1000	3.7	-1	2.6	0	0	6	0
2	5.0	11.1	11.1	1	090	1000	3.7	1	2.6	0	0	52	3
2	5.1	1.7	1.7	1	090	1000	3.7	0	2.6	0	0	6	0
2	5.1	6.6	6.6	1	270	1000	3.7	0	2.6	0	0	10	0
2	5.1	6.5	6.5	1	090	1000	3.7	0	2.6	0	0	6	0
2	5.1	11.4	11.4	1	090	1000	3.7	0	2.6	0	0	10	0
2	5.2	9.4	9.4	1	270	1000	3.9	1	2.6	0	0	10	0
2	5.2	14.5	14.5	1	270	1000	3.9	1	2.6	0	0	10	0
2	5.2	9.5	9.5	1	090	1000	3.9	-1	2.6	0	0	6	0
2	5.2	3.6	3.6	1	090	1000	3.9	-1	2.6	0	0	10	0
2	5.3	3.2	3.2	1	270	1000	3.9	1	2.6	0	0	6	0
2	0.7	2.6	2.6	1	090	1000	5.6	-1	3.0	0	0	10	0
2	0.7	4.8	4.8	1	270	1000	5.6	1	3.0	0	0	10	0
2	3.6	6.0	6.0	1	270	1000	6.4	1	3.0	0	0	6	0

DET	TOT	RNG	LATRNG	RNGSC	RBG	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	0.0	7.6	5.4	2	044	1500	13	-1	3.0	0	1	10	0
1	0.1	6.7	6.6	2	079	1500	13	0	3.0	0	0	10	0
1	0.2	16.0	12.6	2	052	1500	13	-1	3.0	0	1	37	4
1	0.2	1.8	1.8	2	090	1500	13	0	3.0	0	1	10	0
1	0.6	8.2	7.7	1	077	1500	12	-1	3.6	1	1	10	0
1	1.0	10.3	6.8	1	318	1500	10	0	3.0	0	1	6	0
1	1.2	7.6	0.4	1	002	1500	10	0	3.0	0	1	10	0
1	1.5	5.8	5.6	1	072	1500	10	0	3.0	0	0	6	0
1	1.6	9.0	1.5	1	014	1500	10	0	3.0	0	1	6	0
1	1.9	10.5	9.7	1	065	1500	7	0	3.6	0	1	6	0
1	3.3	13.1	1.1	1	355	1500	6	0	3.3	1	0	6	0
1	3.3	4.6	1.7	1	023	1500	6	0	3.3	1	0	10	0
1	3.3	10.0	9.5	1	073	1500	6	0	3.3	1	0	6	0
1	3.8	6.0	3.9	1	317	1500	9	0	3.0	1	1	37	4
1	3.9	13.2	3.0	1	345	1500	9	0	3.0	0	0	45	3
1	4.0	9.4	3.8	1	335	1500	9	0	3.0	0	1	41	3
1	4.3	11.0	4.0	1	019	1500	9	-1	3.0	0	0	6	0
1	4.3	6.0	5.7	1	291	1500	8	0	3.0	0	0	10	0
1	4.4	14.1	10.0	1	314	1500	8	0	3.0	0	1	10	0
1	4.4	3.1	2.4	1	051	1500	8	-1	3.0	0	1	4	0
1	4.4	5.1	0.0	1	000	1500	8	0	3.0	0	1	6	0
1	4.4	12.6	5.8	1	023	1500	8	-1	3.0	0	0	6	0
1	4.5	9.3	8.8	1	288	1500	8	0	3.0	0	0	10	0
1	4.7	11.2	1.3	1	351	1500	5	0	3.0	1	0	10	0
1	4.8	9.3	9.2	1	077	1500	5	0	3.0	1	0	10	0
2	0.1	0.4	0.4	1	270	1500	13	0	3.0	0	1	10	0
2	0.1	0.6	0.6	1	270	1500	13	0	3.0	0	0	10	0
2	0.1	15.9	15.9	1	090	1500	13	0	3.0	0	0	6	0
2	0.2	13.8	13.8	1	090	1500	13	0	3.0	0	1	4	0
2	0.2	11.2	11.2	1	090	1500	13	0	3.0	0	1	6	0
2	0.3	5.7	5.7	1	090	1500	12	0	3.0	1	1	6	0
2	0.3	1.4	1.4	1	090	1500	12	0	3.0	1	1	10	0
2	0.5	0.7	0.7	1	270	1500	12	1	3.6	1	1	10	0
2	0.5	9.4	9.4	1	090	1500	12	-1	3.6	1	1	10	0
2	0.7	3.7	3.7	1	270	1500	12	-1	3.6	1	1	10	0
2	0.7	15.3	15.3	1	270	1500	12	-1	3.6	1	1	6	0
2	0.8	4.7	4.7	1	270	1500	12	-1	3.6	1	1	10	0
2	0.8	5.2	5.2	1	090	1500	12	1	3.6	1	1	10	0
2	0.9	3.6	3.6	1	090	1500	10	0	3.0	1	1	10	0
2	1.0	0.8	0.8	1	270	1500	10	0	3.0	1	1	6	0
2	1.0	10.9	10.9	1	270	1500	10	0	3.0	1	1	6	0
2	1.0	3.8	3.8	1	090	1500	10	0	3.0	0	1	10	0
2	1.1	8.3	8.3	1	270	1500	10	0	3.0	0	1	4	0
2	1.1	15.6	15.6	1	270	1500	10	0	3.0	0	1	37	4
2	1.2	6.2	6.2	1	090	1500	10	0	3.0	0	0	10	0
2	1.2	0.7	0.7	1	270	1500	10	0	3.0	0	0	10	0
2	1.2	10.4	10.4	1	270	1500	10	0	3.0	0	0	6	0
2	1.2	12.0	12.0	1	270	1500	10	0	3.0	0	1	4	0
2	1.3	5.7	5.7	1	090	1500	10	0	3.0	0	1	10	0
2	1.4	10.7	10.7	1	270	1500	10	0	3.0	0	1	10	0
2	1.4	5.1	5.1	1	270	1500	10	0	3.0	0	1	10	0
2	1.4	7.0	7.0	1	090	1500	10	0	3.0	0	1	4	0
2	1.4	13.3	13.3	1	090	1500	10	0	3.0	0	1	6	0
2	1.5	10.9	10.9	1	270	1500	10	0	3.0	0	0	10	0
2	1.5	4.1	4.1	1	270	1500	10	0	3.0	0	0	10	0
2	1.5	11.0	11.0	1	090	1500	10	0	3.0	0	0	4	0
2	1.6	8.5	8.5	1	270	1500	10	0	3.0	0	1	10	0

DET	TOT	RNG	LATRNG	RNGSC	RBG	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	1.6	3.8	3.8	1	090	1500	10	0	3.0	0	1	4	0
2	1.6	13.6	13.6	1	090	1500	10	0	3.0	0	1	10	0
2	1.7	8.0	8.0	1	270	1500	10	0	3.0	1	1	10	0
2	1.6	3.8	3.8	1	270	1500	10	0	3.0	1	1	6	0
2	1.6	6.4	6.4	1	090	1500	10	0	3.0	1	1	6	0
2	1.6	12.0	12.0	1	090	1500	10	0	3.0	1	1	6	0
2	1.9	10.9	10.9	1	270	1500	7	1	3.6	1	1	10	0
2	1.9	0.8	0.8	1	270	1500	7	1	3.6	1	1	10	0
2	1.9	12.5	12.5	1	090	1500	7	-1	3.6	1	1	10	0
2	2.0	2.0	2.0	1	270	1500	7	1	3.6	0	0	10	0
2	2.1	15.5	15.5	1	270	1500	7	-1	3.6	0	0	6	0
2	2.1	5.6	5.6	1	090	1500	7	-1	3.6	0	0	10	0
2	2.1	5.0	5.0	1	090	1500	7	-1	3.6	0	0	10	0
2	2.1	7.8	7.8	1	270	1500	7	-1	3.6	0	0	10	0
2	2.1	15.5	15.5	1	270	1500	7	-1	3.6	0	0	6	0
2	2.3	13.9	13.9	1	090	1500	7	0	2.6	0	1	10	0
2	2.4	9.8	9.8	1	090	1500	7	0	2.6	0	1	6	0
2	2.4	0.7	0.7	1	270	1500	7	0	2.6	0	1	6	0
1	2.4	7.0	6.2	1	289	1500	7	0	2.6	0	1	6	0
2	2.4	14.6	14.6	1	090	1500	7	0	2.6	0	1	10	0
2	2.4	7.7	7.7	1	270	1500	7	0	2.6	0	1	10	0
2	2.5	1.9	1.9	1	090	1500	7	0	2.6	0	1	4	0
2	2.4	13.0	13.0	1	270	1500	7	0	2.6	0	1	6	0
2	2.4	13.2	13.2	1	270	1500	7	0	2.6	0	1	37	4
2	2.6	15.8	15.8	1	090	1500	7	0	2.6	0	0	10	0
2	2.6	9.0	9.0	1	090	1500	7	0	2.6	0	0	10	0
2	2.6	0.7	0.7	1	270	1500	7	0	2.6	0	0	6	0
2	2.6	6.1	6.1	1	270	1500	7	0	2.6	0	0	4	0
2	2.6	12.9	12.9	1	270	1500	7	0	2.6	0	0	6	0
2	2.6	2.6	2.6	1	270	1500	7	0	2.6	0	1	4	0
2	2.6	8.9	8.9	1	270	1500	7	0	2.6	0	1	6	0
2	2.7	15.1	15.1	1	090	1500	7	0	2.6	0	1	10	0
2	2.7	9.7	9.7	1	090	1500	7	0	2.6	0	1	10	0
2	2.7	14.2	14.2	1	270	1500	7	0	2.6	0	1	4	0
2	2.7	15.9	15.9	1	270	1500	7	0	2.6	0	1	41	3
2	3.3	11.4	11.4	1	090	1500	6	-1	3.3	1	0	10	0
2	3.8	5.4	5.4	1	270	1500	8	0	3.0	0	0	6	0
2	3.8	10.1	10.1	1	090	1500	9	0	3.0	0	0	6	0
2	3.8	4.3	4.3	1	090	1500	9	0	3.0	0	0	6	0
2	3.7	7.4	7.4	1	270	1500	8	0	3.0	0	0	54	3
2	3.8	15.0	15.0	1	090	1500	9	0	3.0	1	1	6	0
2	3.8	2.7	2.7	1	090	1500	9	0	3.0	1	1	10	0
2	3.8	2.4	2.4	1	270	1500	9	0	3.0	1	1	6	0
2	3.8	12.6	12.6	1	090	1500	9	0	3.0	1	1	4	0
2	3.9	10.8	10.8	1	090	1500	9	0	3.0	0	0	6	0
2	3.9	5.6	5.6	1	090	1500	9	0	3.0	0	0	4	0
2	3.9	1.3	1.3	1	270	1500	9	0	3.0	0	0	6	0
2	4.0	9.7	9.7	1	090	1500	9	0	3.0	0	1	4	0
2	4.0	3.4	3.4	1	090	1500	9	0	3.0	0	1	6	0
2	4.0	2.0	2.0	1	270	1500	9	0	3.0	0	1	4	0
2	4.1	14.8	14.8	1	090	1500	9	0	3.0	0	1	6	0
2	4.1	14.7	14.7	1	090	1500	9	0	3.0	0	1	4	0
2	4.2	12.5	12.5	1	270	1500	9	0	3.0	0	1	10	0
2	4.2	7.1	7.1	1	270	1500	9	0	3.0	0	1	10	0
2	4.2	5.5	5.5	1	090	1500	9	0	3.0	0	1	4	0
2	4.2	11.6	11.6	1	090	1500	9	0	3.0	0	1	6	0
2	4.3	12.3	12.3	1	270	1500	8	0	3.0	0	0	10	0

DET	TOT	RNG	LATRNG	RNGSC	RBG	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	4.3	9.6	9.6	1	090	1500	8	0	3.0	0	0	4	0
2	4.4	12.6	12.6	1	090	1500	8	0	3.0	0	1	10	0
2	4.5	4.8	4.8	1	270	1500	8	0	3.0	0	0	6	0
2	4.5	11.4	11.4	1	090	1500	8	0	3.0	0	0	6	0
2	4.7	11.5	11.5	1	270	1500	5	1	3.0	1	0	10	0
2	4.7	9.2	9.2	1	090	1500	5	-1	3.0	1	0	6	0
2	4.7	11.9	11.9	1	090	1500	5	-1	3.0	1	0	10	0
1	2.9	2.0	1.7	1	056	1500	7	-1	3.0	0	0	4	0
1	1.2	15.7	15.7	1	270	1500	10	0	3.0	0	1	45	3
2	2.4	4.9	4.9	1	090	1500	7	0	2.6	0	1	6	0
2	2.5	14.3	14.3	1	270	1500	7	0	2.6	0	1	45	3
2	0.1	9.8	9.8	1	090	1500	13	0	3.0	0	0	45	3
2	2.8	14.9	14.9	1	270	1500	7	0	3.0	0	1	10	0
2	2.8	2.6	2.6	1	270	1500	7	0	3.0	0	1	4	0
2	2.8	3.5	3.5	1	090	1500	7	0	3.0	0	1	6	0
2	2.8	9.0	9.0	1	090	1500	7	0	3.0	0	1	4	0
2	2.8	10.7	10.7	1	090	1500	7	0	3.0	0	1	41	3
2	2.9	13.9	13.9	1	270	1500	7	0	3.0	0	0	10	0
2	2.9	4.2	4.2	1	270	1500	7	0	3.0	0	0	6	0
2	2.9	8.0	8.0	1	090	1500	7	0	3.0	0	0	6	0
2	2.9	9.6	9.6	1	090	1500	7	0	3.0	0	0	45	3
2	3.0	8.7	8.7	1	270	1500	7	0	3.0	0	1	6	6
2	3.0	6.2	6.2	1	270	1500	7	0	3.0	0	1	4	0
2	3.0	3.8	3.8	1	090	1500	7	0	3.0	0	1	10	0
2	2.9	8.7	8.7	1	090	1500	7	0	3.0	0	1	6	0
2	2.9	10.0	10.0	1	090	1500	7	0	3.0	0	1	37	2
2	3.0	8.7	8.7	1	270	1500	7	0	3.0	0	0	6	0
2	3.0	6.3	6.3	1	270	1500	7	0	3.0	0	0	6	0
2	3.0	3.9	3.9	1	090	1500	7	0	3.0	0	0	6	0
2	3.1	8.7	8.7	1	090	1500	7	0	3.0	0	0	6	0
2	3.1	13.6	13.6	1	090	1500	7	0	3.0	0	0	54	3
2	4.8	1.8	1.8	1	270	1500	6	1	3.0	1	0	10	0

DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	0.1	7.4	6.9	1	115	1000	7.2	0	2.3	0	0	4	0
1	0.2	4.7	1.7	1	021	1000	7.2	-1	2.3	0	0	10	0
1	0.3	5.2	1.9	1	022	1000	7.2	-1	2.3	0	0	6	0
1	0.5	1.8	0.1	1	000	2000	12.4	-1	2.6	0	0	10	0
1	0.7	7.4	5.1	1	044	2000	11.1	0	2.6	0	0	10	0
1	1.0	3.4	3.4	1	087	2000	5.4	0	2.0	0	0	10	0
1	1.2	6.2	4.2	1	318	2000	5.4	0	2.0	0	0	6	0
1	1.3	6.5	3.8	1	036	2000	5.4	-1	2.0	0	0	10	0
1	1.3	6.4	0.8	1	008	2000	5.4	-1	2.0	0	0	10	0
1	1.4	7.4	4.7	1	040	2000	5.4	-1	2.0	0	0	6	0
1	1.4	10.8	10.6	1	101	2000	5.4	0	2.0	0	0	4	0
1	1.6	6.0	1.0	1	351	2000	9.9	-1	2.6	0	1	10	0
1	1.7	8.2	1.7	1	348	2000	9.9	-1	2.3	0	1	10	0
1	1.7	6.9	5.9	1	121	2000	9.9	0	2.3	0	1	10	0
1	1.8	5.7	5.2	1	249	2000	9.9	0	2.3	0	1	6	0
1	2.0	7.2	7.2	1	276	2000	7.4	0	2.3	0	0	4	0
1	2.0	8.3	8.2	1	101	2000	7.4	0	2.3	0	0	6	0
1	2.1	10.1	9.8	1	280	2000	7.4	0	2.3	0	0	54	3
1	2.2	10.0	8.8	1	059	2000	7.4	1	2.3	0	0	6	0
1	2.2	6.1	6.1	1	280	2000	7.4	-1	2.3	0	0	10	0
1	2.2	13.0	13.0	1	271	2000	7.4	-1	2.3	0	0	10	0
1	2.3	6.7	0.6	1	006	2000	7.4	-1	2.3	0	0	10	0
1	2.3	6.5	4.1	1	320	2000	7.4	0	2.3	0	0	4	0
1	2.3	8.3	7.5	1	066	2000	7.4	-1	2.3	0	0	10	0
1	2.4	5.8	5.8	1	270	2000	7.4	0	2.3	0	0	10	0
1	2.4	11.2	0.8	1	004	2000	7.4	-1	2.3	0	0	4	0
1	2.4	10.7	5.4	1	330	2000	7.4	-1	2.3	0	0	6	0
1	2.7	2.9	1.5	1	034	2000	10.5	-1	2.6	0	1	6	0
1	2.7	3.7	1.2	1	328	2000	10.5	-1	2.6	0	1	6	0
1	2.8	11.6	4.4	1	358	2000	10.5	-1	2.0	0	1	10	0
1	3.1	13.1	11.2	1	059	2000	7.0	1	2.0	0	0	6	0
1	3.2	6.0	5.8	1	105	2000	7.0	0	2.0	0	0	6	0
1	3.3	5.6	4.0	1	315	2000	7.0	0	2.0	0	0	41	3
1	3.4	5.5	1.5	1	344	2000	7.0	0	2.0	0	0	41	3
1	3.5	4.2	0.9	1	012	2000	5.4	-1	2.0	0	0	6	0
1	3.8	6.7	1.4	1	348	2000	9.3	-1	2.6	0	1	10	0
1	3.8	8.7	8.4	1	288	2000	9.3	-1	2.6	0	1	6	0
1	3.8	4.2	0.9	1	350	2000	9.3	-1	2.6	0	1	10	0
1	4.3	8.2	6.3	1	310	2000	6.2	0	2.3	0	0	10	0
1	4.5	6.3	4.9	1	051	2000	6.2	-1	2.3	0	0	10	0
1	4.5	6.4	2.1	1	019	2000	6.2	-1	2.3	0	0	10	0
1	4.5	8.9	7.5	1	302	2000	6.2	0	2.3	0	0	10	0
1	4.5	9.2	3.4	1	338	2000	7.0	-1	2.3	0	0	6	0
1	4.8	10.3	0.9	1	355	2000	8.6	-1	2.6	0	1	10	0
1	4.8	10.3	6.6	1	320	2000	8.6	-1	2.6	0	1	6	0
2	0.1	5.8	5.8	1	090	1000	7.2	-1	2.3	0	0	6	0
2	0.2	15.7	15.7	1	090	1000	7.2	-1	2.3	0	0	4	0
2	0.2	14.4	14.4	1	090	1000	7.2	0	2.3	0	0	10	0
2	0.2	11.8	11.8	1	090	1000	7.2	0	2.3	0	0	10	0
2	0.3	15.4	15.4	1	090	1000	7.2	0	2.3	0	0	6	0
2	0.3	6.0	6.0	1	090	1000	7.2	0	2.3	0	0	6	0
2	0.5	9.8	9.8	1	090	2000	11.1	0	2.6	0	0	10	0
2	0.6	8.4	8.4	1	090	2000	11.1	0	2.6	0	0	10	0
2	0.6	3.4	3.4	1	270	2000	11.1	0	2.6	0	0	10	0
2	0.7	14.7	14.7	1	270	2000	11.1	0	2.6	0	0	6	0
2	0.7	4.7	4.7	1	270	2000	11.1	0	2.6	0	0	10	0
2	0.9	3.1	3.1	1	090	2000	6.4	0	2.0	0	0	6	0

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DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	0.9	0.8	0.8	1	270	2000	6.4	0	2.0	0	0	6	0
2	0.9	10.4	10.4	1	270	2000	6.4	0	2.0	0	0	6	0
2	1.0	6.1	6.1	1	270	2000	5.4	0	2.0	0	0	10	0
2	1.0	14.9	14.9	1	270	2000	5.4	0	2.0	0	0	6	0
2	1.0	9.2	9.2	1	270	2000	5.4	0	2.0	0	0	10	0
2	1.1	0.4	0.4	1	270	2000	5.4	-1	2.0	0	0	6	0
2	1.1	10.4	10.4	1	270	2000	5.4	-1	2.0	0	0	4	0
2	1.1	15.2	15.2	1	270	2000	5.4	-1	2.0	0	0	10	0
2	1.2	5.0	5.0	1	090	2000	5.4	1	2.0	0	0	4	0
2	1.2	10.0	10.0	1	090	2000	5.4	1	2.0	0	0	10	0
2	1.3	13.1	13.1	1	090	2000	5.4	0	2.0	0	0	10	0
2	1.3	9.4	9.4	1	090	2000	5.4	0	2.0	0	0	6	0
2	1.3	9.2	9.2	1	270	2000	5.4	0	2.0	0	0	10	0
2	1.4	4.6	4.6	1	270	2000	5.4	0	2.0	0	0	6	0
2	1.4	8.6	8.6	1	270	2000	5.4	0	2.0	0	0	6	0
2	1.6	10.8	10.8	1	270	2000	9.9	0	2.3	0	1	10	0
2	1.6	11.7	11.7	1	090	2000	9.9	C	2.3	0	1	6	0
2	1.6	9.6	9.6	1	090	2000	9.9	0	2.3	0	1	6	0
2	1.8	15.4	15.4	1	270	2000	9.9	0	2.3	0	1	10	0
2	1.8	7.7	7.7	1	270	2000	9.9	0	2.3	0	1	6	0
2	1.8	4.8	4.8	1	090	2000	9.9	0	2.3	0	1	10	0
2	1.8	14.8	14.8	1	090	2000	9.9	0	2.3	0	1	10	0
2	2.0	12.4	12.4	1	090	2000	7.4	0	2.3	0	0	6	0
2	2.0	1.0	1.0	1	270	2000	7.4	0	2.3	0	0	6	0
2	2.1	5.7	5.7	1	270	2000	7.4	0	2.3	0	0	6	0
2	2.1	2.8	2.8	1	090	2000	7.4	0	2.3	0	0	10	0
2	2.1	12.7	12.7	1	090	2000	7.4	0	2.3	0	0	10	0
2	2.1	9.4	9.4	1	270	2000	7.4	0	2.3	0	0	10	0
2	2.1	0.0	0.0	1	090	2000	7.4	0	2.3	0	0	10	0
2	2.2	1.1	1.1	1	270	2000	7.4	-1	2.3	0	0	4	0
2	2.2	14.8	14.8	1	270	2000	7.4	-1	2.3	0	0	41	3
2	1.3	14.1	14.1	1	090	2000	5.4	0	2.0	0	0	54	3
2	2.3	14.4	14.4	1	270	2000	7.4	1	2.3	0	0	6	0
2	2.3	9.2	9.2	1	090	2000	7.4	-1	2.3	0	0	41	3
2	2.4	4.0	4.0	1	090	2000	7.4	0	2.3	0	0	54	3
2	2.4	3.4	3.4	1	090	2000	7.4	0	2.3	0	0	10	0
2	2.4	0.4	0.4	1	270	2000	7.4	0	2.3	0	0	6	0
2	2.4	9.0	9.0	1	270	2000	7.4	0	2.3	0	0	10	0
2	2.5	13.0	13.0	1	090	2000	7.4	0	2.3	0	0	6	0
2	2.5	13.0	13.0	1	090	2000	7.4	0	2.3	0	0	37	4
2	2.5	14.6	14.6	1	270	2000	7.4	0	2.3	0	0	6	0
2	2.7	9.0	9.0	1	090	2000	10.5	0	2.6	0	1	10	0
2	2.7	11.4	11.4	1	270	2000	10.5	0	2.6	0	1	10	0
2	2.7	9.2	9.2	1	090	2000	10.5	0	2.6	0	1	52	3
2	3.1	7.4	7.4	1	270	2000	7.0	0	2.0	0	0	6	0
2	3.1	7.4	7.4	1	270	2000	7.0	0	2.0	0	0	37	4
2	3.2	15.0	15.0	1	090	2000	7.0	0	2.0	0	0	10	0
2	3.2	0.3	0.3	1	090	2000	7.0	0	2.0	0	0	54	3
2	3.2	2.0	2.0	1	090	2000	7.0	0	2.0	0	0	10	0
2	3.2	11.4	11.4	1	090	2000	7.0	0	2.0	0	0	10	0
2	3.3	2.4	2.4	1	270	2000	7.0	-1	2.0	0	0	10	0
2	3.3	4.8	4.8	1	090	2000	7.0	1	2.0	0	0	10	0
2	3.3	9.5	9.5	1	090	2000	7.0	1	2.0	0	0	4	0
2	3.4	15.6	15.6	1	270	2000	7.0	1	2.0	0	0	4	0
2	3.4	10.8	10.8	1	270	2000	7.0	1	2.0	0	0	10	0
2	3.4	3.6	3.6	1	270	2000	7.0	1	2.0	0	0	10	0
2	3.5	8.1	8.1	1	270	2000	7.0	0	2.0	0	0	10	0

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DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	3.5	6.8	6.8	1	270	2000	7.0	0	2.0	0	0	54	3
2	3.5	12.0	12.0	1	270	2000	5.4	0	2.0	0	0	6	0
2	3.5	1.1	1.1	1	090	2000	5.4	0	2.0	0	0	37	4
2	3.6	11.2	11.2	1	270	2000	5.4	0	2.0	0	0	4	0
2	3.8	0.6	0.6	1	270	2000	9.3	0	2.6	0	1	52	3
2	3.8	10.9	10.9	1	270	2000	9.3	0	2.6	0	1	6	0
2	4.2	13.0	13.0	1	090	2000	6.2	0	2.3	0	0	6	0
2	4.2	6.5	6.5	1	270	2000	6.2	0	2.3	0	0	4	0
2	4.2	0.6	0.6	1	270	2000	6.2	0	2.3	0	0	6	0
2	4.2	8.6	8.6	1	090	2000	6.2	0	2.3	0	0	6	0
2	4.2	13.9	13.9	1	270	2000	6.2	0	2.3	0	0	37	4
2	4.2	5.5	5.5	1	270	2000	6.2	0	2.3	0	0	6	0
2	4.2	3.0	3.0	1	090	2000	6.2	0	2.3	0	0	10	0
2	4.2	12.9	12.9	1	090	2000	6.2	0	2.3	0	0	10	0
2	4.3	10.5	10.5	1	270	2000	6.2	0	2.3	0	0	54	3
2	4.3	9.3	9.3	1	270	2000	6.2	0	2.3	0	0	10	0
2	4.3	0.0	0.0	1	000	2000	6.2	0	2.3	0	0	10	0
2	4.3	15.0	15.0	1	270	2000	6.2	-1	2.3	0	0	41	3
2	4.3	1.4	1.4	1	270	2000	6.2	-1	2.3	0	0	4	0
2	4.3	8.5	8.5	1	090	2000	6.2	1	2.3	0	0	6	0
2	4.4	11.4	11.4	1	090	2000	6.2	-1	2.3	0	0	10	0
2	4.4	6.6	6.6	1	090	2000	6.2	-1	2.3	0	0	4	0
2	4.4	3.2	3.2	1	270	2000	6.2	1	2.3	0	0	6	0
2	4.5	14.6	14.6	1	090	2000	6.2	0	2.3	0	0	10	0
2	4.5	15.7	15.7	1	090	2000	7.0	0	2.3	0	0	54	3
2	4.5	10.8	10.8	1	090	2000	7.0	0	2.3	0	0	6	0
2	4.6	13.1	13.1	1	090	2000	7.0	0	2.3	0	0	37	4
2	4.6	12.0	12.0	1	090	2000	7.0	0	2.3	0	0	6	0
2	4.6	6.0	6.0	1	090	2000	7.0	0	2.3	0	0	6	0
2	4.6	7.3	7.3	1	270	2000	7.0	0	2.3	0	0	6	0
2	4.8	12.6	12.6	1	090	2000	8.6	0	2.6	0	1	6	0
2	4.8	0.1	0.1	1	270	2000	8.6	0	2.6	0	1	10	0
2	4.8	9.8	9.8	1	270	2000	8.6	0	2.6	0	1	10	0
2	4.8	10.5	10.5	1	090	2000	8.6	0	2.6	0	1	6	0
2	3.1	5.2	5.2	1	090	2000	7.0	0	2.0	0	0	4	0
2	4.3	13.2	13.2	1	270	2000	6.2	-1	2.3	0	0	10	0
2	4.6	6.5	6.5	1	090	2000	7.0	0	2.3	0	0	4	0

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DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
1	0.1	5.0	0.1	1	359	1500	7.0	1	1.0	0	0	6	0
1	0.2	5.8	0.9	1	004	1500	7.0	0	1.0	0	0	6	0
1	0.4	6.6	0.1	1	002	1500	7.0	1	1.3	0	0	6	0
1	0.5	10.7	4.9	1	046	1500	7.0	0	1.3	0	0	6	0
1	0.8	4.0	4.0	1	090	1500	8.0	1	1.3	0	0	6	0
1	1.1	2.5	0.3	1	357	1500	8.0	1	1.3	0	0	10	0
1	1.4	5.0	1.7	1	350	1500	7.0	1	1.3	0	0	10	0
1	1.5	4.2	4.2	1	270	1500	7.0	1	1.3	0	0	10	0
1	1.9	4.5	1.8	1	335	1500	7.0	0	1.3	0	0	10	o
1	2.1	4.5	0.0	1	000	1500	7.0	1	1.3	0	0	10	0
1	2.2	2.1	1.2	1	[illegible]	1500	7.0	0	1.3	0	0	6	0
1	2.4	5.7	1.0	1	010	1500	7.0	1	1.3	0	0	6	0
1	2.5	6.1	0.9	1	355	1500	7.0	1	1.3	0	0	10	0
1	4.1	1.2	1.1	1	008	1500	3.0	-1	1.0	0	0	54	3
1	4.3	4.3	0.6	1	007	1500	3.0	0	1.0	0	0	37	4
2	0.1	10.0	10.0	1	090	1500	7.0	-1	1.0	0	0	10	0
2	0.2	8.4	8.4	1	090	1500	7.0	-1	1.0	0	0	6	0
2	0.2	13.6	13.6	1	090	1500	7.0	-1	1.0	0	0	6	0
2	0.4	9.3	9.3	1	090	1500	7.0	-1	1.3	0	0	10	0
2	0.5	6.5	6.5	1	090	1500	7.0	-1	1.3	0	0	10	0
2	0.5	1.6	1.6	1	270	1500	7.0	-1	1.3	0	0	10	0
2	0.6	13.6	13.6	1	270	1500	7.0	-1	1.3	0	0	10	0
2	0.6	4.1	4.1	[illegible]	270	1500	7.0	-1	1.3	0	0	10	0
2	0.6	4.8	4.8	1	090	1500	7.0	1	1.3	0	0	6	0
2	0.0	3.7	3.7	1	270	1500	8.0	-1	1.3	0	0	6	0
2	0.8	14.7	14.7	1	270	1500	8.0	-1	1.3	0	0	6	0
2	0.9	8.5	8.5	1	270	1500	8.0	-1	1.3	0	0	6	0
2	0.9	5.0	5.0	1	270	1500	8.0	-1	1.3	0	0	10	0
2	0.9	11.7	11.7	1	270	1500	8.0	-1	1.3	0	0	10	0
2	0.9	15.4	15.4	1	270	1500	8.0	-1	1.3	0	0	10	0
2	0.9	5.2	5.2	1	090	1500	8.0	1	1.3	0	0	6	0
2	1.1	10.8	10.8	1	270	1500	8.0	1	1.3	0	0	6	0
2	1.1	10.1	10.1	1	090	1500	8.0	-1	1.3	0	0	10	0
2	1.1	6.4	6.4	1	090	1500	8.0	-1	1.3	0	0	10	0
2	1.2	2.9	2.9	1	090	1500	8.0	-1	1.3	0	0	6	0
2	1.2	9.0	9.0	1	090	1500	8.0	-1	1.3	0	0	6	0
2	1.2	2.1	2.1	1	270	1500	8.0	1	1.3	0	0	6	0
2	1.2	9.4	9.4	1	270	1500	8.0	1	1.3	0	0	6	0
2	1.4	10.5	10.5	1	270	1500	7.0	1	1.3	0	0	6	0
2	1.4	11.8	11.8	1	090	1500	7.0	-1	1.3	0	0	6	0
2	1.5	7.9	7.9	1	090	1500	7.0	-1	1.3	0	0	10	0
2	1.5	10.2	10.2	1	090	1500	7.0	-1	1.3	0	0	10	0
2	1.6	3.0	3.0	1	270	1500	7.0	-1	1.3	0	0	10	0
2	1.6	11.6	11.6	1	270	1500	7.0	-1	1.3	0	0	10	0
2	1.6	7.1	7.1	1	270	1500	7.0	-1	1.3	0	0	6	0
2	1.6	6.5	6.5	1	090	1500	7.0	1	1.3	0	0	10	0
2	1.6	15.4	15.4	1	090	1500	7.0	1	1.3	0	0	6	0
2	1.9	13.9	13.9	1	090	1500	7.0	1	1.3	0	0	6	0
2	1.9	6.6	6.6	1	090	1500	7.0	1	1.3	0	0	6	0
2	1.9	4.5	4.5	1	270	1500	7.0	-1	1.3	0	0	6	0
2	1.9	13.9	13.9	1	270	1500	7.0	-1	1.3	0	0	4	0
2	1.9	1.8	1.8	1	090	1500	7.0	1	1.3	0	0	6	0
2	1.9	14.7	14.7	1	270	1500	7.0	-1	1.3	0	0	37	4
2	1.9	5.3	5.3	1	090	1500	7.0	1	1.3	0	0	10	0
2	2.0	14.7	14.7	1	270	1500	7.0	-1	1.3	0	0	54	3
2	2.0	5.3	5.3	1	270	1500	7.0	-1	1.3	0	0	10	0
2	2.0	12.4	12.4	1	270	1500	7.0	-1	1.3	0	0	10	0

DET	TOT	RNG	LATRNG	RNGSC	RBg	ALT	WDSP	SWDIR	HS	PRECIP	WHCAPS	SIZE	TGTREF
2	2.0	15.5	15.5	1	090	1500	7.0	1	1.3	0	0	6	0
2	2.1	7.2	7.2	1	090	1500	7.0	-1	1.3	0	0	10	0
2	2.1	3.8	3.8	1	270	1500	7.0	1	1.3	0	0	10	0
2	2.1	10.3	10.3	1	270	1500	7.0	1	1.3	0	0	10	0
2	2.1	9.3	9.3	1	090	1500	7.0	-1	1.3	0	0	54	3
2	2.2	7.1	7.1	1	270	1500	7.0	1	1.3	0	0	6	0
2	2.2	9.3	9.3	1	090	1500	7.0	-1	1.3	0	0	37	4
2	2.2	8.4	8.4	1	090	1500	7.0	-1	1.3	0	0	4	0
2	2.2	12.5	12.5	1	270	1500	7.0	1	1.3	0	0	6	0
2	2.5	12.6	12.6	1	270	1500	7.0	1	1.3	0	0	10	0
2	2.5	3.1	3.1	1	270	1500	7.0	1	1.3	0	0	10	0
2	2.5	5.6	5.6	1	090	1500	7.0	-1	1.3	0	0	10	0
2	3.7	7.0	7.0	1	270	1500	5.0	-1	1.0	0	0	10	0
2	3.7	1.7	1.7	1	090	1500	5.0	1	1.0	0	0	10	0
2	3.7	2.5	2.5	1	270	1500	5.0	-1	1.0	0	0	6	0
2	3.7	11.1	11.1	1	090	1500	5.0	1	1.0	0	0	10	0
2	3.9	1.0	1.0	1	090	1500	5.0	-1	1.0	0	0	6	0
2	3.9	11.9	11.9	1	090	1500	5.0	1	1.0	0	0	6	0
2	3.9	0.0	0.0	1	000	1500	5.0	0	1.0	0	0	37	4
2	4.0	7.0	7.0	1	090	1500	3.0	1	1.0	0	0	6	0
2	4.0	4.4	4.4	1	090	1500	3.0	1	1.0	0	0	10	0
2	4.0	11.4	11.4	1	090	1500	3.0	1	1.0	0	0	10	0
2	4.2	0.4	0.4	1	090	1500	3.0	-1	1.0	0	0	10	0
2	4.2	6.4	6.4	1	270	1500	3.0	1	1.0	0	0	10	0
2	4.3	3.0	3.0	1	270	1500	3.0	1	1.0	0	0	6	0
1	2.6	4.2	1.0	1	324	1500	7.0	-1	1.3	0	0	10	0
1	2.9	3.8	2.5	1	346	1500	6.0	0	1.0	0	0	4	0
2	3.0	3.5	3.5	1	270	1500	6.0	-1	1.0	0	0	54	3
1	3.2	4.0	0.3	1	002	1500	6.0	0	1.0	0	0	37	4
2	1.6	14.6	14.6	1	270	1500	7.0	-1	1.3	0	0	56	3
2	2.6	7.8	7.8	1	090	1500	7.0	1	1.3	0	0	10	0
2	2.7	4.1	4.1	1	090	1500	7.0	1	1.3	0	0	6	0
2	2.9	7.0	7.0	1	090	1500	6.0	1	1.0	0	0	6	0
2	2.9	13.3	13.3	1	090	1500	6.0	1	1.0	0	0	6	0
2	2.9	4.2	4.2	1	270	1500	6.0	-1	1.0	0	0	37	4
2	3.0	9.6	9.6	1	090	1500	6.0	1	1.0	0	0	10	0
2	3.0	6.0	6.0	1	090	1500	6.0	1	1.0	0	0	10	0
2	3.0	1.3	1.3	1	270	1500	6.0	-1	1.0	0	0	10	0
2	3.1	2.8	2.8	1	270	1500	6.0	1	1.0	0	0	10	0
2	3.1	0.6	0.6	1	270	1500	6.0	1	1.0	0	0	54	3
2	3.1	10.0	10.0	1	270	1500	6.0	1	1.0	0	0	10	0
2	3.2	13.8	13.8	1	270	1500	6.0	1	1.0	0	0	10	0
2	3.3	1.4	1.4	1	270	1500	6.0	1	1.0	0	0	4	0
2	3.3	11.0	11.0	1	270	1500	6.0	1	1.0	0	0	6	0
2	3.5	8.0	8.0	1	270	1500	7.0	1	1.3	0	0	6	0
2	3.5	3.2	3.2	1	270	1500	7.0	1	1.3	0	0	10	0
2	3.5	11.8	11.8	1	270	1500	7.0	1	1.3	0	0	10	0

BLANK

APPENDIX B
LATERAL RANGE CURVE COEFFICIENTS

The following table lists the values for the constants of the model used to define the curves in figures 2-2, 2-3, and 2-5 through 2-8. The equation defining the curve is found in section 1.4.2.4.

Figure	A	B	C	D
2-2	0.032	2.68	-0.71	-0.89
2-3	0.19	1.60	-1.47	-1.93
2-5	0.52	4.52	-2.35	-3.52
2-6	0.82	2.71	-11.62	-13.55
2-7	1.51	5.0	2.48	7.01
2-8	0.12	1.37	-1.19	-1.55