TP 12441E

TARGET DETECTION EXPERIMENT
PHASE I - EXPERIMENT PLANNING

by

OCEANS Ltd.

for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

May 1995

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Reginald B. Fitzgerald

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16. Abstract

During past Search and Rescue (SAR) detection experiments targets have been moored. With the advancement of positioning and recording capabilities it is now feasible to conduct these experiments using drifting targets, thus allowing for the collection of data in a more realistic manner while allowing for the collection of data for related SAR research. This report includes an experiment plan that provides a framework for future experiments as well as recommendations with respect to data collection requirements for future experiments. During the course of the work a validation trial was conducted off Nova Scotia in the fall of 1994. During the trials, daylight searches were conducted for 4- and 6-person life rafts. This report provides the results of the analysis of these trials. Also, a number of recommendations are made with respect to the upcoming SAR detection trials planned for the fall of 1995.

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16. Résumé

Au cours des dernières expériences de détection de recherche et sauvetage, les cibles étaient amarrées. Avec les nouvelles possibilités de mise en position et les capacités d'enregistrement, il est maintenant envisageable de mener ces expériences en utilisant des cibles flottantes, permettant ainsi la collecte de données de façon plus réaliste, tout en autorisant une collecte de données relatives au travail de recherche et sauvetage. Ce rapport contient un plan d'expérience fournissant une structure pour les expériences à venir ainsi que des recommandations ayant trait aux exigences pour la collecte de données pour les expériences prochaines. Au cours des travaux, un essai de validation a été conduit au large de la Nouvelle-Écosse, pendant l'automne 1994. Lors de ces essais, les recherches menées en plein jour ont été conduites sur des radeaux de sauvetage de 4 et 6 places. Les résultats de cette analyse sont contenus dans ce rapport. Également, un certain nombre de recommandations sont faites concernant les prochains essais de détection de recherche et sauvetage prévus pour l'automne de 1995.

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EXECUTIVE SUMMARY

This multi-phase project is a continuation of similar projects conducted in 1986 in Placentia Bay, Newfoundland and again in 1987, 1988 and 1990 on the Canso Bank off Nova Scotia. The search platforms involved in these experiments included the CCGS "Jackman", the CCGS "Sir William Alexander" the CCGS "Alert" and the USCGC "Vigorous". Certain aircraft have also taken part in these experiments. Sensors have included visual searches, night vision goggles, certain ship based radar and certain airborne radars. The targets have included 4- and 6-person canopied life rafts configured with and without canopy lights. During radar searches some life rafts were outfitted with radar reflectors to represent persons onboard.

Transport Canada, through this project, has embarked on an effort to develop valid Probability of Detection (POD) models by carrying out more realistic search experiments using free drifting objects. It is acknowledged that this approach will be slower than the traditional fixed target approach but, in the end, should arrive at more thorough POD models while allowing for data collection to support related research.

The overall project objectives are to develop methodologies for conducting POD field trials using free drifting objects, to conduct visual and electronic detection trials using common SAR targets and to use the collected data to model the various platform/sensor/target combinations.

The main objectives of this Phase I work were to develop an experiment plan that will be used in future detection experiments conducted during the various phases of this project and to conduct one validation trial based upon that plan. Part of the development of the experiment plan was to determine the data collection requirements for future detection experiments.

Recommended Data Collection Requirements

The following recommendations are made with respect to POD data collection requirements for future experiments:

TARGETS:

- o Persons in the water (PIWs) in a variety of configurations;
- o 4-person to 25-person orange life rafts in a variety of configurations; and,
- o Small boats ranging from 16 to 30 feet in a variety of configurations.

SENSORS/SEARCH TYPE:

- o Daylight searches using binoculars;
- o Nighttime searches using binoculars;
- o Nighttime searches using Night Vision Goggles (NVGs); and,
- o Standard marine radars.

EMERGING TECHNOLOGIES:

- o Airborne Synthetic Aperture Radar;
- o Spaceborne Synthetic Aperture Radar;
- o Advanced Shipborne Radar Signal Processing; and,
- o Data Fusion.

SEARCH PLATFORMS:

- o Coast Guard vessels;
- o Coast Guard fixed and rotary wing aircraft;
- o Department of National Defense (DND) fixed and rotary wing aircraft;
- o Fisheries & Oceans Vessels and Surveillance Aircraft; and,
- o Other government agency aircraft such as the Canadian Centre for Remote Sensing (CCRS) Convair 580.

INDEPENDENT VARIABLES:

Recommendations are given within the report for the collection of data on variables to be tested for significance during future detection experiments. The variables to be tested fall within the following recommended categories:

- o Target particulars;
- o Search platform particulars;
- o Environmental conditions;
- o Ambient light conditions; and,
- o Human factors.

Validation Trials

Validation trials were conducted from the CCGC "Bickerton" off Shelburne, N.S. during the fall of 1994. Support was provided by the CCGS "Sir William Alexander". The targets included 4- and 6-person orange canopied life rafts. Only daylight searches were conducted, and the targets were free drifting and were deployed with and without drogues. In total six (6) searches were conducted generating 70 detection opportunities. The analysis results showed that lateral range was the only significant independent variable and the resulting sweep width was 4.6 nautical miles.

Experiment Plan

The Experiment Plan contains information and discussion on the following subject matter:

- Data Collection Methodology;
- Experiment Management;
- Field Experiment Preparations; and,
- Field Operations Methodology.

Recommendation for SAR '95

The following recommendations are made for the detection experiment scheduled for the fall of 1995:

1. Augment the NVG data set for 600 Class Vessels searching for life rafts outfitted with retro reflective tape.

2. Begin collecting the data set for 600 Class Vessels conducting night visual searches for life rafts with retro reflective tape.

3. Begin collecting the data set for 600 Class Vessels conducting daytime visual searches for small white boats.

4. Begin collecting the data set for 600 Class Vessels conducting daytime visual searches for PIWs wearing orange survival suits.

5. Begin collecting the data set for 600 Class Vessels conducting radar searches for small boats without radar reflectors.

6. Begin collecting the data set for 600 Class Vessels conducting radar searches for small boats with radar reflectors.

7. Carry out searches using the TITAN system.

8. Carry out searches using data fusion (TITAN - FLIR/LLLTV).

9. Invite CCRS to conduct searches with the Convair 580 using C band SAR against life rafts outfitted similarly to those in the Canso Bank 1990 experiment.

10. Invite DND to participate in the search experiment using their search aircraft.

11. Continue the investigation of human factors involved with SAR, specifically in the areas of training, experience, and fatigue for visual and electronic observers.

12. As part of the 1995 project, review the USCG detection data in detail and update the data requirements of the Canadian Coast Guard marine SAR resources as appropriate.

13. As part of the 1995 project, develop a software package that will assist in the experiment search planning for drifting targets.

SOMMAIRE

Ce projet multiphases se veut une continuité de projets similaires qui ont été menés en 1986 sur la Baie Placentia, à Terre-Neuve, et en 1987, 1988 et 1990 sur le Banc Canso au large de la Nouvelle-Écosse. Les plates-formes de recherches participant à ces expériences sont le «NGCC Jackman», le «NGCC Sir William Alexander» le «NGCC Alert» et le «NGCCUS Vigorous». Certains avions ont également pris part à ces expériences. Des détecteurs visuels, des lunettes de vision nocturne, certains radars de navires de même que des radars d'avions ont été utilisés. Les objets flottants comprennaient des radeaux de sauvetage couverts de 4 et 6 places, avec ou sans lumière sur le toît. Au cours des recherches utilisant les radars, quelques radeaux de sauvetage étaient munis de réflecteurs pour représenter les personnes à bord.

Par l'entremise de ce projet, Transports Canada a entrepris un effort pour développer des modèles valides de «Probabilité de détection» (POD), tout en mettant à exécution des expériences de recherches plus réalistes utilisant des objets en dérive libre. Malgré que cette méthode soit reconnue comme étant plus lente que la méthode traditionnelle utilisant des objets fixes, les résultats devraient donner des modèles «POD» plus consciencieux, tout en permettant une collecte de données pour appuyer la recherche connexe.

Les objectifs de l'ensemble du projet sont de développer des méthodologies pour mener des essais de «POD» sur le terrain en utilisant des objets en dérive libre, de mener des essais de détection visuelle et électronique en utilisant des objectifs de R-S d'usage courant et d'utiliser les données recueillies pour modeler les diverses plates-formes/ détecteurs/combinaisons d'objectifs.

Les buts principaux du travail de la phase I consistaient à développer un plan d'expérience qui sera utilisé dans les expériences de détection à venir et qui seront menées pendant les diverses phases de ce projet et à mener un essai de validation basé sur ce plan. Une partie du développement de ce plan visait à identifier les exigences ayant trait à la collecte de données pour les expériences de détection à venir.

<u>Exigences recommandées pour la collecte de données</u>

Les recommandations qui suivent concernent les exigences de la collecte de données pour des expériences à venir :

CIBLES :

- Personnes à la mer dans une variété de configurations;
- Radeaux de sauvetage orange de 4 à 25 places dans une variété de configurations;
- Petites embarcations de l'ordre de 16 à 30 pieds dans une variété de configurations.

DÉTECTEURS/GENRE DE RECHERCHE :

- Recherches en plein jour en utilisant des jumelles;
- Recherches de nuit en utilisant des jumelles;
- Recherches de nuit en utilisant des lunettes de vision nocture (LVN);
- Radars marins courants.

TECHNOLOGIES ÉMERGENTES :

- Radar à synthèse d'ouverture aéroporté;
- Radar à synthèse d'ouverture spatioporté;
- Système embarqué pour le traitement des signaux radars;
- Fusion des données.

PLATES-FORMES DE RECHERCHE :

- Vaisseaux de la Garde côtière;
- Aéronefs à voilure fixe et tournante appartenant à la Garde côtière canadienne;
- Aéronefs à voilure fixe et tournante appartenant au ministère de la Défense nationale;
- Vaisseaux et aéronefs de surveillance du ministère des Pêches et Océans;
- Autres aéronefs du secteur public tels que le Convair 580 du Centre canadien de télédétection.

VARIABLES INDÉPENDANTES :

Des recommandations pour la collecte de données sur les variables à être mises à l'épreuve pour leur signification au cours des expériences de détection à venir sont données à l'intérieur de ce rapport. Les variables à être testées se trouvent à l'intérieur des catégories recommandées suivantes :

- o Précisions sur les cibles;
- o Précisions sue les plates-formes;
- o Conditions environnementales;
- o Conditions de lumière ambiante;
- o Facteurs humains.

Essais de Validation

Des essais de validation ont été menés à partir du «NGCC Bickerton» au large de Shelburne, en Nouvelle Écosse, au cours de l'automne de 1994. Le soutien a été pourvu par le «NGCC Sir William Alexander». Les cibles comprenaient des radeaux de sauvetage couverts orange de 4 et 6 places. Les recherches ont été menées uniquement en plein jour, les cibles étaient en dérive libre et ont été déployées avec et sans ancres flottantes. Un total de six recherches ont été effectuées produisant 70 occasions de détection. Les résultats de l'analyse ont montré que la portée latérale était la seule variable indépendante significative et que l'ampleur de l'envergure résultante était de 4,6 milles marins.

Plan d'expérience

Le plan d'expérience renferme de l'information et une discussion sur les sujets suivants:

- o La méthodologie de la collecte de données;
- o La gestion de l'expérience;
- o La préparation de l'expérience sur le terrain;
- o La méthodologie des opérations sur le terrain;
- o L'analyse des données «POD».

Recommandations pour R-S '95

Les recommandations suivantes sont faites pour les prochaines expériences de détection prévues pour l'automne 1995 :

1. Augmenter l'ensemble des données LVN pour les vaisseaux de catégorie 600 recherchant des radeaux de sauvetage équipés de rubans rétroréflecteurs;

2. Amorcer la collecte de l'ensemble des données LVN pour les vaisseaux de catégorie 600 menant des recherches visuelles nocturnes pour des radeaux de sauvetage avec des rubans rétroréflecteurs.

3. Amorcer la collecte de l'ensemble des données pour les vaisseaux de catégorie 600 menant des recherches en plein du jour pour de petites embarcations blanches.

4. Amorcer la collecte de l'ensemble des données pour les vaisseaux de catégorie 600 menant des recherches en plein jour pour des personnes à la mer portant une combinaison de survie orange.

5. Amorcer la collecte de l'ensemble des données pour les vaisseaux de catégorie 600 menant des recherches en utilisant des radars pour de petites embarcations sans réflecteurs de radars.

6. Amorcer la collecte de l'ensemble des données pour les vaisseaux de catégorie 600 menant des recherches en utilisant des radars pour de petites embarcations munies de réflecteurs de radars.

7. Mettre à exécution des recherches utilisant le système de radar TITAN.

8. Mettre à exécution des recherches utilisant la fusion des données mettant à contribution les systèmes «TITAN - FLIR/LLLTV (Forward Looking Infrared/Low Light Level TV».

9. Inviter le Centre canadien de télédétection à mener des recherches en utilisant le Convair 580 utilisant la bande R-S C contre les radeaux de sauvetage équipés de façon simila ire à ceux de l'expérience du Banc de Canso de 1990.

10. Inviter la Défense nationale à participer aux expériences de recherche en utilisant ses avions de recherche.

11. Continuer l'investigation des facteurs humains mis à contribution dans la R-S, plus particulièrement dans les domaines de la formation, de l'expérience et de la fatigue pour les observateurs visuels et électroniques.

12. À l'intérieur du projet de 1995, réviser les données de détection de la USCG en détail et mettre à jour les exigences des données pour les ressources marines de R-S de la Garde côtière canadienne, si nécessaire.

13. À l'intérieur du projet de 1995, développer un logiciel qui aidera à planifier l'expérimentation pour les cibles à la dérive.

Table of Contents

Table of Contents Cont'd

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This document constitutes OCEANS Ltd. Final Report for the project entitled "**TARGET DETECTION EXPERIMENT - PHASE I - EXPERIMENT PLANNING**".

Section 1 provides the background for this multi-phase project. Section 2 reviews the objectives of this Phase I project as well as the objectives of the overall project. Section 3 presents data collection recommendations and section 4 discusses the validation trials that were carried out as part of this project. Section 5 presents the results from the validation trial data while section 6 presents the experiment plan. Finally section 7 presents conclusions regarding this phase of the work and recommendations for the full scale detection experiment planned for the fall of 1995.

1.1 Background

This multi-phase project is a continuation of similar projects that were conducted in 1986 in Placentia Bay, Newfoundland and again in 1987, 1988 and 1990 on the Canso Bank off Nova Scotia. The projects were carried out on behalf of the Canadian Coast Guard (CCG) and the Transportation Development Centre (TDC) and were supported by the United States Coast Guard (USCG). During these experiments SAR targets were moored and a variety of search tracks were used for the purpose of collecting relevant data for developing Probability of Detection (POD) curves for certain platform/sensor/target combinations.

The search platforms that were involved in these experiments included the CCGS "Jackman" (600 Class), the CCGS "Sir William Alexander" (1100 Class) and the CCGS "Alert" (600 Class) as well as the USCGC "Vigorous". Certain aircraft have also taken part in these experiments, including the Provincial Airlines King Air B200, the Canadian Centre for Remote Sensing (CCRS) Convair 580 and a HU-25A aircraft from the USCG. Sensors have included visual searches, night vision goggles, certain ship based radar and certain airborne radars. The targets have included 4- and 6-person canopied life rafts configured with and without canopy lights. During radar searches some life rafts were outfitted with radar reflectors to represent persons onboard.

Transport Canada is embarking on an effort to develop valid POD models using drifting objects. It is considered that search experiments will be more realistic. It is acknowledged that this approach will be slower than the traditional fixed target approach but, in the end, should arrive at more thorough POD models while allowing for data collection to support related research.

2.0 PROJECT OBJECTIVES

The overall project objectives as defined by the Statement of Work (SOW) are to develop methodologies for conducting POD field trials using free drifting objects, to conduct visual and electronic detection trials using common SAR targets and to use the collected data to model the various platform/sensor/target combinations.

2.1 Phase I Objective: Experiment Planning

The objective of Phase I was to develop an experiment plan that will be used in future detection experiments conducted during the various phases of this project. The primary sub-objectives unique to Phase I included the following:

- For a variety of common platform/sensor/target combinations, determine the data collection requirements necessary for developing valid POD models;
- Solicit input with respect to data collection for related SAR programs and program such data collection into the experiment plan;
- Develop an experiment plan that will provide the framework for future detection trials;
- Conduct a validation trial based upon the experiment plan;
- Finalize the experiment plan based on the results and findings of the validation trials;
- Analyze the validation trial data; and,
- Produce a Final Report containing the following components:
    - the experiment plan;
    - a description of the validation trials;
    - validation trial data analysis results;
    - recommendation for future work; and,
    - recommendations for the next full scale experiment.

2.2 Phase II Objective: Full Scale Experiment

The objective of Phase II will be to conduct a full scale experiment in the fall of 1995 during which a number of sensors will be tested and data will be collected in accordance with the established experiment plan.

2.3 Phase III Objective: Data Reduction and Analysis

The objective of Phase III will be to use the collected data to model the platform/sensor/target combinations tested, as well as to increase the accuracy of target drift models, assess search pattern effectiveness, and generally improve the state of the art in SAR modelling.

3.0 DATA COLLECTION REQUIREMENT RECOMMENDATIONS

The following subsections contain information on the data collection requirements recommended for future POD trials as well as the data requirements requested for related SAR projects.

3.1 Common SAR Targets and Sensors

To date the following target/sensor combination have been tested in Canadian Coast Guard detection experiments:

- o Daylight visual for 4- and 6-person yellow and orange life rafts;
- o Nighttime visual for 4- and 6-person life rafts with retro reflective tape and canopy lights;
- o NVGs for 4- and 6-person life rafts with retro reflective tape and canopy lights;
- o NVGs for 4- and 6-person life rafts with retro reflective tape and without canopy lights;
- o Standard ships radar for 4- and 6-person life rafts without radar reflectors;
- o Standard ships radar for 4-person life rafts outfitted with radar reflectors simulating 4 persons on board;
- o APS-504(V)5 search radar for 4-person life rafts outfitted with radar reflectors simulating 4 persons on board; and,
- o Synthetic Aperture Radar for 4-person life rafts outfitted with radar reflectors simulating 4 persons on board.

The USCG for the most part have focused on targets that have a high probability of becoming real SAR targets, including PIWs, life rafts and small boats. The work carried out to date by the CCG falls in line with this approach.

In view of the above, it is recommended that the focus for the future should be on the following targets and sensors:

TARGETS:

- o PIWs with orange survival suits;
- o PIWs with survival suits outfitted with reflective tape and without safety lights;

- PIWs with survival suits outfitted with safety lights and reflective tape;
- Orange life rafts ranging from 4-person to 25-person;
- Life rafts ranging from 4-person to 25-person with retro-reflective tape and without canopy lights;
- Life rafts ranging from 4-person to 25-person with retro-reflective tape and canopy lights;
- Life rafts ranging from 4-person to 25-person with radar reflectors simulating appropriate number of persons on board;
- Small white boats ranging from 16 to 30 feet;
- Small boats ranging from 16 to 30 feet without radar reflector; and,
- Small boats ranging from 16 to 30 feet with radar reflector.

SENSORS:

- Daylight searches using binoculars;
- Nighttime searches using binoculars;
- Nighttime searches using NVGs; and,
- Standard marine radars.

3.2 Emerging Technologies for Marine SAR

In addition to collecting data for the development of valid POD models for the more common platform/sensor/target combinations, allowance has to be made for investigating new technologies that may increase SAR effectiveness with respect to target detection. New technologies should be investigated as thoroughly as possible in terms of practicality and performance before they are tested in any field trials. The following paragraphs describe the emerging technologies that are recommended for testing in future detection experiments.

Airborne Synthetic Aperture Radar (SAR)

It is recommended that detection data be collected using the Canada Centre for Remote Sensing (CCRS) C/X band SAR on the Convair 580. The concentration should be on real-time performance of the C band SAR against drifting targets. During the 1990 experiment this radar performed very well in the detection of moored life rafts with radar reflectors simulating four (4) persons on board. Having the targets moored may have assisted in the image processing resulting in a better performance than had the targets been free drifting.

Spaceborne Synthetic Aperture Radar (SAR)

Spacebased SAR has the potential to provide some level of detection performance on small seaborne targets. RADARSAT could be used in certain situations to assist the Canadian Coast Guard in Search and Rescue. It would be desirable to inform parties with potential interest in this application of upcoming trials so that data acquisition activities may be coordinated. Data from the ERS-1 satellite could provide useful baseline performance of Spaceborne SAR.

If spaceborne radar data were to be included in the program it would be important to include targets that the radar could be expected to detect for reference. It is recommended that a target with a known radar cross section in the order of 100 m^2 be deployed as one of the targets.

Advanced Shipborne Radar Signal Processing

The TITAN radar signal processor shows great potential for use in search and rescue. Informal tests on the Coast Guard vessels Alert and Sir William Alexander have demonstrated the ability of the system to detect small search and rescue targets in rough seas. It would be beneficial to assess the ability of this system to improve radar searching on Coast Guard vessels. There is a significant potential that the system may increase sweep width for radar searches. Results from the TITAN system should be compared directly with results obtained from standard ship radars. The impact of false detections also needs to be addressed during the analysis of the detection data.

The TITAN display system may be attached to existing radar systems and provides advanced signal processing of the radar video signal. The system incorporates pulse to pulse processing to improve radar sensitivity and remove radar interference, uniform weight scan to scan averaging to smooth sea and rain clutter and CFAR to remove the sea and rain clutter background. The system is designed to interface with most radar systems. Access is required to unprocessed radar video, radar trigger, antenna azimuth and ship's gyro data. GPS position data is required to provide ground stabilization for the scan to scan processing. It is expected that a temporary installation of a TITAN system could be carried out with Coast Guard assistance in one to two days with a few hours to demobilize. A couple of hours of training would be sufficient to bring a ship's crew up to speed with the display functions.

The display system is very similar to a conventional radar display in functionality so that real-time detections could be registered by the radar observer. The detection may be noted in range and bearing and/or latitude and longitude using the display cursor controlled by a trackball. It is recommended that the unit be interfaced to one of the newer radars presently in use by the Coast Guard. Functionally, the TITAN display is slaved to its interfacing radar so that if the radar is placed on medium pulse then the TITAN display automatically switches to medium pulse.

Data Fusion

It is expected that in the future various infrared and low light level type sensors may be available for search operations, including the range-gated illuminator and ISTEC Inc. FLIR/LLLTV system. One of the problems associated with the use of multiple sensors is the difficulty of fusing data such that efficient real-time use is possible. At present all sensors on Coast Guard vessels require separate operators and coordination (and confirmation) between sensors must be done verbally or manually.

One of the problems with the infrared system tested earlier was that it was typically only useful in detection when operating with a narrow field of view. This is a problem when conducting a search as it takes a considerable amount of time to scan the full field of view. This type of sensor may be better suited to a confirmation/identification role. For example, targets identified by a radar operator could be identified and located using the infrared system.

With the movement towards PC based systems on vessels it is now possible to acquire and manage various forms of image data. This would include video data available from an infrared system. It is recommended that systems such as the FLIR/LLLTV and TITAN radar display systems be integrated using essentially off-the-shelf hardware. As an example, a suggested package could have the FLIR/LLLTV image displayed on a portion of the radar display and updated at regular intervals. The radar display system could output commands to the FLIR/LLLTV control system to point the camera to the area identified by the radar operators curser. This approach would fully integrate both the radar and FLIR/LLLTV sensors permitting efficient use by a single operator.

3.3 Search Platforms

3.3.1 Coast Guard Vessels

Table 3.1 presents an overall view of the Canadian Coast Guard vessels that are available for SAR missions. Classes 100 to 600 are referred to as primary SAR vessels but any of the classes may be tasked to assist in a SAR mission.

3.3.2 Other Search Platforms

In addition to the Coast Guard Vessel Fleet there are other platforms that are routinely or may in the future be involved in marine SAR and should be evaluated in terms of establishing POD models. These include the following:

- CCG fixed and rotary wing aircraft;
- DND fixed and rotary wing aircraft;
- Fisheries & Oceans Vessels and Surveillance Aircraft; and,
- Other government agency aircraft such as the Canadian Centre for Remote Sensing (CCRS) Convair 580.

Table 3.1
CCG Ship Information

Ship Type	Description	Operation Capabilities	Vessel	Particulars Len/Wdt/Drf/Spd m/ m/ m/ kts
1500*	Polar Icebreaker	Year round operation - all Arctic waters.		
1400*	Medium Polar Icebreaker	Year round operation - all Arctic waters.		
1300*	Heavy Gulf Icebreaker	Large ship escort in severe Gulf of St. Lawrence and Atlantic ice and weather conditions. Capable of extended season operations through areas of ice zone 6 or less severity.	Louis St. Laurent	112/24/10/18 kt
1200*	Medium gulf/river icebreaker	Large ship escort in southern Canadian waters as well as Arctic areas during the summer season.	Henry Larsen Des Groseillers Pierre Radisson Norman Rogers Sir John Franklin	100/20/7/17 kt 98/20/7/16 kt 98/20/7/16 kt 90/19/6/15 kt 98/20/7/16 kt
	Heavy Icebreaker/ Supply Tug		Terry Fox	88/18/8/15 kt

* Denotes helicopter carrying capability.

Table 3.1 Continued

Ship Type	Description	Operation Capabilities	Vessel	Particulars Len/Wdt/Drf/Spd m/ m/ m/ kts
1100*	Major Navaids Tender/Light icebreaker	Buoy handling and medium cargo; small to medium vessel escort in southern Canadian waters and sub Arctic waters.	George R. Pearkes Martha L. Black Griffon J.E. Bernier Sir Wilfred Laurier Sir William Alexander Edward Cornwallis Sir Humphrey Gilbert Ann Harvey	83/16/6/16 kt 83/16/6/16 kt 71/15/5/14 kt 70/15/5/14 kt 83/16/6/16 kt 83/16/6/16 kt 83/16/6/16 kt 69/15/5/13 kt 83/16/6/16 kt
1050*	Medium Navaids Tender/Light icebreaker	Buoy handling, restricted to mainly deck cargo; small to medium vessel escort in moderate ice conditions south of the Arctic.	Samuel Risely Earl Grey	70/14/5/14 kt 70/14/5/13 kt
1000*	Medium Navaids Tender/Ice strengthened	Buoy handling and medium cargo capacity. Small to medium vessel escort in more restricted and shallow waters.	Simcoe Bartlett Tracy Provo Wallis Tupper Simon Fraser	55/12/4/13 kt 58/13/5/13 kt 55/12/4/13 kt 64/13/4/11 kt 62/13/5/13 kt 62/13/4/14 kt
900	Small Navaids Tender/Ice strengthened	Buoy handling in sheltered waters, medium cargo, navigation in light ice conditions, including small vessel escort and harbour breakout.	Sir James Douglas Namao Montmagny Robert Foulis	46/9/3/12 kt 34/9/2/12 kt 45/9/3/12 kt 32/8/2/12 kt

* Denotes helicopter carrying capability.

Table 3.1 Continued

Ship Type	Description	Operation Capabilities	Vessel	Particulars Len/Wdt/Drf/Spd m/ m/ m/ kts
800	Small Navaids Tender	Checking and servicing aids in restricted, shallow waters; ability to lift small floating aids.	Caribou Isle Cove Isle Gull Isle Ile Saint-Ours Ile Des Barques Partridge Island	23/6/1.4/11 kt 23/6/1.4/10 kt 23/6/1.4/10 kt 23/6/1.4/11 kt 23/6/1.4/11 kt 23/6/1.4/11 kt
700	Special River Navaids Tender	Shallow draft, high endurance vessel capable of carrying out all tasks in Mackenzie river system.	Nahidik Dumit Tembah Miskanaw Eckaloo	53/15/2/14 kt 49/12/1.6/13 kt 38/8/0.9/12 kt 20/6/1.2/10 kt 49/13/1.2/13 kt
600*+	Large SAR Cutter	High endurance, all weather vessel capable of providing SAR and a range of other offshore operations.	Mary Hichens Sir Wilfred Grenfell	64/14/6/15 kt 68/15/5/16 kt
500	Intermediate SAR Cutter	Medium endurance, moderate weather patrol, close offshore operations.	Gordon Reid John Jacobson	50/11/4/17 kt 50/11/4/17 kt
400	Small SAR Cutter	Medium range, moderate speed vessel, capable of all weather operation in semi-sheltered waters, station mode.	Point Henry Point Race Cape Hurd Spume Spray Isle Rouge	22/6/1.7/20 kt 22/6/1.7/20 kt 22/6/1.7/20 kt 21/5/1.6/13 kt 21/5/1.6/20 kt 21/5/1.7/13 kt

* Denotes helicopter carrying capability.
+ Same basic type as Type 1050

Table 3.1 Continued

Ship Type	Description	Operation Capabilities	Vessel	Particulars Len/Wdt/Drf/Spd m/ m/ m/ kts
300	SAR Lifeboat	Medium range lifeboat, capable of all-weather operation in semi-sheltered waters, station mode.	Bamfield Tofino Port Hardy Tobermory Westfort Cap Goelands Souris Westport Clarke's Harbour Sambro Louisbourg Port Mouton Cap-Aux-Meules Burin Burgeo Shippegan	13/4/1/13 kt 13/4/1/12 kt 13/4/1/13 kt 13/4/1/12 kt 13/4/1/12 kt 13/4/1/13 kt 13/4/1/15 kt 14/4/1.2/16 kt 13/4/1.2/14 kt 13/4/1.5/15 kt 13/4/1.0/13 kt 13/4/1.0/15 kt 13/4/1.2/14 kt 13/4/1.0/13 kt 13/4/1.0/13 kt 13/4/1.0/12 kt
300A	SAR High Endurance Lifeboat	Long range lifeboat, capable of all-weather operation in close offshore waters, station mode.	Bickerton	16/5/1.5/18 kt
300B	SAR Medium Endurance Lifeboat	Medium range lifeboat, capable of all-weather operation in semi-sheltered waters, station mode.	CGR-100	14/4/0.7/27 kt
200	Small SAR Cutter/Ice Strengthened	Small, ice strengthened ship, capable of SAR operation in ice-infested waters, station mode.	Harp Hood	23/8/2.5/10 kt 23/8/2.5/10 kt

Table 3.1 Continued

Ship Type	Description	Operation Capabilities	Vessel	Particulars Len/Wdt/Drf/Spd m/ m/ m/ kts
100	Small Sar Utility Craft	Moderate to fast; all-weather operation in sheltered waters, station mode.	Osprey Mallard Skua CG119 Sora Bittern Avocet Sterne	12/4/1.3/26 kt 12/4/1.3/26 kt 12/4/1.3/26 kt 12/4/1.0/18 kt 12/4/1.2/26 kt 12/4/1.2/26 kt 11/4/0.8/17 kt 12/4/1.3/26 kt
IRB	Inshore Rescue Boat	Small, fast rescue boat capable of limited rescue operations in inshore/sheltered waters under moderate conditions; station mode; 25 kt speed.		
ACV	Air Cushion Vehicle	SAR Hovercraft configured capable of general purpose rescue operation in shallow waters under moderate weather conditions; station mode; 50 kt speed.		

Legend:
- Len - Vessel Length
- Wdt - Vessel Beam
- Drf - Vessel Draft
- Spd - Maximum Vessel Speed

3.4 Independent Variables

Tables 3.2 to 3.4 present the recommended variables to be tested for significance during future detection experiments.

Table 3.2
Ship-Based Daylight Visual Searches
Variables

Target	SRU*	Environmental	Ambient Light	Human Factors
Type Size Colour	Speed Lookout Height Heave Pitch Roll	Cloud Visibility Precipitation Wind Speed Wave Height White Caps Air Temp. Water Temp.	Relative Sun Azimuth	Lookout Posn. Experience Time on Task

* SRU - Search and Rescue Unit

Table 3.3
Ship-Based Night Searches
Variables

Target	SRU	Environmental	Ambient Light	Human Factors
Type Size Illumination	Speed Lookout Height Heave Pitch Roll	Cloud Visibility Precipitation Wind Speed Wave Height White Caps Air Temp. Water Temp.	Moon Elevation Moon Visibility Artificial Light Level.	Lookout Posn. Experience Time on Task

Table 3.4
Ship-Based Radar Searches
Variables

Target	SRU	Environmental	Ambient Light	Human Factors
Type Size Reflectivity	Speed Scanner Height Range Scale Heave Pitch Roll	Precipitation Wind Speed Wave Height Air Temp. Water Temp.		Experience Time on Task

For other types of searches such as airborne or new technology, the above variables can be modified to fit the specific requirement.

3.5 Data Collection Review

3.5.1 Canadian Coast Guard Experiments

Tables 3.5 to 3.7 provide a summary of POD data collected during CCG detection experiments to date while Table 3.8 summarizes the visual search data including Night Vision Goggle (NVG) searches by vessel class as per Canadian Coast Guard classification.

Table 3.5
Visual Searches

PLATFORM	**SENSOR**	**TARGET**	**OPP** ***	**ENVIRONMENTAL** Vis(nm), Wnd(kt), Sea(m)
Jackman Bridge	Visual Day	4-person orange rafts	56	1/8-15, 2-25, 0.4-1.9
SWA* Bridge	Visual Day	4- and 6- person orange/yellow rafts	585	1/8-15, 0-43, 0.6-3.0
	Visual Night	4- and 6- person rafts with lights	130	5-15, 8-40, 1.0-2.5
	NVG's	4- and 6- person rafts without lights	62	4-15, 10-32, 0.9-2.8
SWA M.I**	Visual Day	4- and 6- person orange rafts	32	15, 15-34, 1.6-2.4
	NVG's	4- and 6- person rafts with lights	9	10-15, 12-20, 1.2-1.3
	NVG's	4- and 6- person rafts without lights	15	8-15, 12-20, 1.2-1.3
Alert Bridge	Visual Day	4- and 6- person orange/yellow rafts	361	1.5-15, 4-34, 0.7-2.7
	NVG's	4- and 6- person rafts with lights	184	1.5-15, 2-35, 1.0-3.0

* Sir William Alexander
** Monkey Island
*** Target Detection Opportunities

Note: A target detection opportunity is defined as a target available for detection within the horizon of the lookout or sensor.

Table 3.5 Continued
Visual Searches

PLATFORM	SENSOR	TARGET	OPP	ENVIRONMENTAL Vis(nm), Wnd(kt), Sea(m)
Alert Bridge	NVG's	4- and 6- person rafts without lights	36	2.5-15,3-34, 0.9-2.2
Alert M. I.	Visual Day	4- and 6- person orange/yellow rafts	44	8-15, 8-30, 1.3-2.1
Vigorous Bridge	Visual Day	4- and 6- person orange/yellow rafts	375	0.5-10, 0-37, 0.5-4.2
	NVG's	4- and 6- person rafts with lights	118	3-10, 5-32, 1.0-2.6
	NVG's	4- and 6- person rafts without lights	55	4-12, 4-28, 0.9-2.1
Vigorous M.I.	Day Visual	4- and 6- person orange/yellow rafts	365	0.5-10, 0-37, 0.3-4.2
	NVG's	4- and 6- person rafts with lights	110	4-10, 5-26, 1.-2.4
	NVG's	4- and 6- person rafts without lights	38	4-12, 4-28, 0.9-2.1

Table 3.6
Airborne Radar Searches

PLATFORM	SENSOR	TARGET	OPP	ENVIRONMENTAL Wnd(kt), Sea(m)
King Air B200	APS504 (V)5	4- and 6- person rafts with 1 and 2m^2 radar reflectors	293	7-34, 1.0-3.0
Convair 580	SAR*	4- and 6- person rafts with 1 and 2m^2 radar reflectors	82	16-30, 1.0-2.4

* Synthetic Aperture Radar

Table 3.7
Ship Radar Searches

PLATFORM	SENSOR	TARGET	OPP	ENVIRONMENTAL Wnd(kt), Sea(m)
Jackman	Sperry 127E	4-person rafts with $2m^2$ radar reflectors	46	2-25, 0.4-1.9
	Sperry 127E	4-person rafts without radar reflectors	29	2-25, 0.4-1.9
SWA	Sperry 340	4- and 6-person rafts without reflectors	NA*	3-43, 0.9-3.0
	Sperry 340	4- and 6-person rafts with $2m^2$ reflectors	NA	3-43, 0.9-3.0
	Path Finder	4- and 6-person rafts without reflectors	NA	3-40, 0.6-2.4
	Path Finder	Spar buoy with $2m^2$ reflector mounted at 1.3 m.	NA	3-40, 0.6-2.4
	Path Finder	Melsweep Radar Transponder	NA	3-40, 0.6-2.4
	Sperry 4016	4- and 6-person rafts with $2m^2$ reflectors	NA	3-43, 0.6-3.0
	Sperry 4016	Spar buoy with $2m^2$ reflector mounted at 1.3 m.	NA	3-43, 0.6-3.0
	Sperry 4016	Melsweep Radar Transponder	NA	3-43, 0.6-3.0

* The opportunity count for the surface radar searches was not available; however, it is believed that the data set is small.

Table 3.8
Visual Search Summary

CLASS	SENSOR	TARGET	OPP	ENVIRONMENTAL Vis(nm), Wnd(kt), Sea(m)
1100	Visual Day	4- and 6-person orange & yellow rafts	617	1/8-15, 0-43, 0.6-3.0
	Visual Night	4- and 6- person rafts with lights and reflective tape	130	5-15, 8-40, 1.0-2.5
	NVGs	4- and 6-person rafts with lights and reflective tape	9	10-15, 12-20, 1.2-1.3
	NVGs	4- and 6-person rafts with reflective tape & no lights	77	4-15, 10-32, 0.9-2.8
600	Visual Day	4- and 6-person orange & yellow rafts	1201	1/8-15, 2-34, 0.4-4.2
	NVGs	4- and 6-person rafts with lights and reflective tape	412	1.5-15, 2-35, 1.0-3.0
	NVGs	4- and 6-person rafts with reflective tape & no lights	129	2.5-15, 3-34, 0.9-2.2
300A	Visual Day	4- and 6-person orange rafts	70	6+, 2-28, 1.0-2.5

Note: In Table 3.8 the USCGC "Vigorous" has been combined with the 600 class vessels and searches carried out from the bridge and monkey island have been combined.

3.5.2 USCG Experiments

The more recent work carried out by the USCG has concentrated on the evaluation of NVGs against targets that were expected to be actual search targets during actual SAR missions. These targets included simulated Persons in the Water (PIWs), 4- and 6-person life rafts and 18 and 21 foot boats. The primary search platforms included 41 foot Utility Boats and Helicopters.

The PIWs were deployed in various configurations that included the following:

- without lights or reflective tape;
- with strobes;
- with safety lights; and
- with reflective tape.

The life rafts were deployed with and without reflective tape and no lighting while the boats were deployed without lights or reflective tape.

The USCG has also carried out considerable work in the area of daylight visual detection. Again the targets were PIWs, small boats and life rafts. The search platforms included rotary and fixed wing aircraft, 41 foot Utility Boats, 44 foot Motored Life Boats and 82/95 foot Patrol Boats. Many of the results from these experiments have already been integrated into the National SAR Manual. The USCG has carried out little in the way of night visual searches using binoculars.

The USCG has concentrated on collecting data from its Coast Guard boats under 100 feet. With the exception of the data collected from the USCGC Vigorous during the joint Canso Bank experiment conducted in 1990, little detection data has been collected from larger class vessels of the USCG.

3.6 POD Data Requirements for Future Experiments

3.6.1 General

In order to progress as quickly as possible with the data collection over the long term it will be necessary to evaluate all the USCG data collected to date and apply the results where appropriate to the Canadian data sets. The aim here is to avoid unnecessary duplication in data collection. Another important issue will be to combine data sets from different observation platforms where possible. This will also help to expedite data collection.

The amount of data that needs to be collected to obtain reasonable POD models for one platform/sensor/target combination has been discussed with the USCG. They have suggested that 500 to 600 target opportunities would be reasonable, provided there was good distribution within the individual variables. These numbers should be considered applicable to all platform/sensor/target combinations.

3.6.2 POD Data Collection Requirement Summary

What follows is a summary of the data collection requirements recommended for future experiments in order to develop POD models for common platform/sensor/target combinations.

The data collection requirements summary is outlined in two (2) tables. Table 3.9 assigns a data set number to each search type and sensor/target combination. Table 3.10 shows the POD model requirements recommended for each search platform.

In reviewing the tables the following points should be noted:

1. The table should be updated after careful review of all the USCG detection data. It is quite likely that some, if not most, of the data collection by the USCG will be applicable to the smaller class vessels (< 30 m) and to certain rotary and fixed wing aircraft.

2. POD models developed for a certain class vessel will likely be appropriate for vessel classes of similar size or larger until models can be developed for the larger class vessel.

3. The combining of data sets from different platforms should expedite the data collection process.

Table 3.9
Sensor/Target Combinations

Data Set #.	Search Type	Sensor	Targets
1.	Day	Visual	PIWs with orange survival suits.
2.	Night	Visual	PIWs with survival suits outfitted with safety lights and reflective tape.
3.		Visual	PIWs with survival suits outfitted with reflective tape and without safety lights.
4.	Night	NVGs	PIWs with survival suits outfitted with safety lights and reflective tape.
5.		NVGs	PIWs with survival suits outfitted with reflective tape and without safety lights.
6.	Day	Visual	Orange life rafts ranging from 4-person to 25-person.
7.	Night	Visual	Life rafts ranging from 4-person to 25-person with retro-reflective tape and canopy lights.
8.		Visual	Life rafts ranging from 4-person to 25-person with retro-reflective tape and without canopy lights.
9.	Night	NVGs	Life rafts ranging from 4-person to 25-person with retro-reflective tape and canopy lights.
10.		NVGs	Life rafts ranging from 4-person to 25-person with retro-reflective tape and without canopy lights.
11.	Day/Night	Radar	Life rafts ranging from 4-person to 25-person with radar reflectors simulating appropriate number of persons on board.
12.	Day	Visual	Small white boats ranging from 16 to 30 feet.
13.	Day/Night	Radar	Small boats ranging from 16 to 30 feet with radar reflector.
14.		Radar	Small boats ranging from 16 to 30 feet without radar reflector.

Table 3.10
POD Model Requirements
Platform Vs. Data Set

Platform	Data Set	Remarks
1300 Class Vessel	1-14	
1200 Class Vessel	1-14	
1100 Class Vessel	1-5, 7-14	Data set 8 requires 400 data points. Data set 10 requires 450 data points.
1050 Class Vessel	1-14	
1000 Class Vessel	1-14	
900 Class Vessel	1-14	
800 Class Vessel	1-14	
700 Class Vessel	1-14	
600 Class Vessel	2-14	Data set 9 requires 100 data points. Data set 10 requires 400 data points.
500 Class Vessel	1-14	
400 Class Vessel	1-14	
300A Class Vessel	1-14	Data set 6 requires 400 data points.
300B Class Vessel	1-14	
300 Class Vessel	1-14	
200 Class Vessel	1-14	
100 Class Vessel	1-14	
Rotary Wing Aircraft*	1-10, 12	
Fixed Wing Aircraft*	1-10, 12	

* Normally involved in Marine SAR

3.7 Data Requirements for Related SAR Projects

Part of the reasoning for using drifting targets in future detection experiments is that it will allow for the collection of data for related SAR projects. These projects include:

- Sea Keeping Performance of SAR Vessels;
- Electronic Opportunities in SAR;
- Drift Errors in Search Modelling;
- Leeway Dynamics;
- CANSARP Communications Interface;
- CASP/CANSARP Comparison;
- CANSARP Search Pattern Evaluation;
- Effects of Diversion on POD; and,
- Operator Fatigue.

Early in the project OCEANS Ltd. circulated a letter to CCG, TDC, USCG, DFO and interested groups in the private sector inviting them to submit data requirements that would be of benefit to related SAR projects or research that they were involved in or may be involved with in the future. Additionally, it was asked that they include logistics information for collecting such data.

OCEANS Ltd. received a number of responses and the data requests are listed here.

DATA REQUESTS FOR RELATED SAR PROJECTS

Fleet Technology

- Wave spectra over reasonable periods and updated at least hourly.

USCG

- An emphasis on target types bigger than life rafts, perhaps small fishing boats and disabled sail boats.
- Seed the search area with drifter buoys in order to check the drift data, conduct an experiment with satellite imagery, and evaluate the function of the buoys.

- o Emphasize the human factors involved with SAR. Issues such as training, experience, and fatigue should be quantified for visual and electronic observers.

- o Check the adequacy of available environmental data bases.

Canadian Coast Guard

- o Specify the period and angle of roll and pitch and include the accelerations measured at the lookout position.

- o With respect to lookout information provide the following:

  - fitness measurements of each individual;
  - experience in lookout duties;
  - full report of his/her daily activities; and,
  - effectiveness of NVGs if used.

- o With respect to the drift error study provide the following:

  - position: latitude and longitude, time (UTC) of each search target;
  - wind direction and speed at each target position or closest vessel's true wind direction and speed with her position; and,
  - water temperature, pressure, and depth at each search target's position or water temperature and pressure measurements measured as close as possible to the target's position.

Transportation Development Centre

- o Information on life raft configuration including:

  - inflated condition; and,
  - loading and position of ballast bags.

- o Barometric pressure measurements.

- o Detailed weather conditions of the previous 24 hours.

- o Comparison of the target drift with CANSARP prediction.

OCEANS Ltd.

- o Collect leeway data on as many objects as possible, especially small boats.

- o The Rescue Coordination Centre (RCC) should be involved in the planning strategy of search tracks with respect to CANSARP so that search results can be used by CCG in the evaluation of CANSARP generated search patterns.

The above requests for data collection for related SAR projects and the logistics for collecting such data are addressed in section 6.5.

3.8 Recommendations Summary

The following summarizes the proposed data collection requirements in point form.

COMMON TARGETS (section 3.1)

- o PIWs with orange survival suits;
- o PIWs with survival suits outfitted with reflective tape and without safety lights;
- o PIWs with survival suits outfitted with safety lights and reflective tape;
- o Orange life rafts ranging from 4-person to 25-person;
- o Life rafts ranging from 4-person to 25-person with retro-reflective tape and without canopy lights;
- o Life rafts ranging from 4-person to 25-person with retro-reflective tape and canopy lights;
- o Life rafts ranging from 4-person to 25-person with radar reflectors simulating appropriate number of persons on board;
- o Small white boats ranging from 16 to 30 feet;
- o Small boats ranging from 16 to 30 feet without radar reflector; and,
- o Small boats ranging from 16 to 30 feet with radar reflector.

COMMON SENSORS (section 3.1)

- Daylight searches using binoculars;
- Nighttime searches using binoculars;
- Nighttime searches using NVGs; and,
- Standard marine radars.

EMERGING TECHNOLOGIES (section 3.2)

- Airborne Synthetic Aperture Radar (SAR);
- Spaceborne Synthetic Aperture Radar (SAR);
- Advanced Shipborne Radar Signal Processing; and,
- Data Fusion.

SEARCH PLATFORMS (section 3.3)

- Coast Guard vessels
- CCG fixed and rotary wing aircraft;
- DND fixed and rotary wing aircraft;
- Fisheries & Oceans Vessels and Surveillance Aircraft; and,
- Other government agency aircraft such as the Canadian Centre for Remote Sensing (CCRS) Convair 580.

The early focus should be to develop models for targets offering the worse case scenario. For night searches these would be targets without lights. The vessels that should be focused on include the 600, 1100 and 300 class vessels. The 600 and 300 are primary SAR vessels for which some data has already been collected. A significant amount of data has also been collected for an 1100 class vessel. Vessels of this class are increasingly assigned to primary SAR duties.

4.0 VALIDATION TRIAL

4.1 Trial Objectives

The overall objectives of the validation trials were to assess the feasibility of using drifting targets during a SAR detection experiment and also to assess the feasibility of collecting data during the experiment for related SAR R & D efforts. The specific objectives of the trials were as follows:

Primary Objective

Conduct POD trials for daylight visual searches using drifting common SAR targets.

Secondary Objective

During the POD trials collect leeway data on one (1) drifting common SAR target. (See appendix "B" for preliminary data analysis)

4.2 Trial Location

The base of operations for the validation trials was Shelburne, NS. The experiment took place in the vicinity of the Roseway Bank off Shelburne. The area was selected because it was in the general vicinity of a planned Canadian and United States Coast Guard SAR exercise (SAREX) that was taking place in the vicinity of Georges Bank and the Bay of Fundy. The resources used for the detection trials were also used to support the SAREX which lasted for 2 days. The general experiment area is shown in Figure 4.1.

The actual operations area for the validation trials was approximately 35 nm by 36 nm. An illustration of the operations area is shown in Figure 4.2. The operations area is depicted by a 35 nm by 36 nm search grid comprising 104 waypoints, which are identified alphanumerically. Search patterns were selected using any combination of waypoints throughout the grid. This system simplified the communication of search pattern information among the participating vessels.

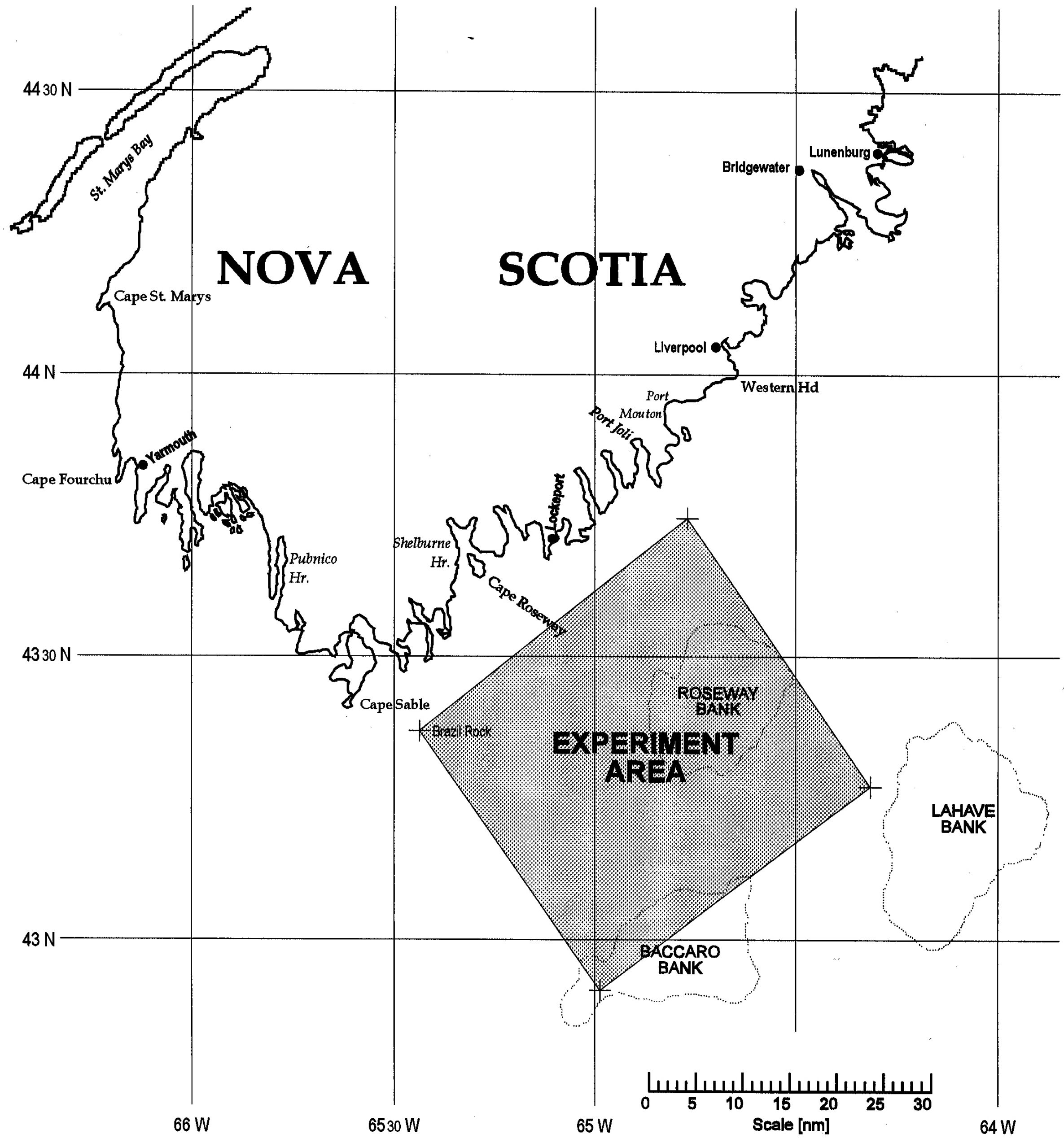


Figure 4.1: Experiment Area

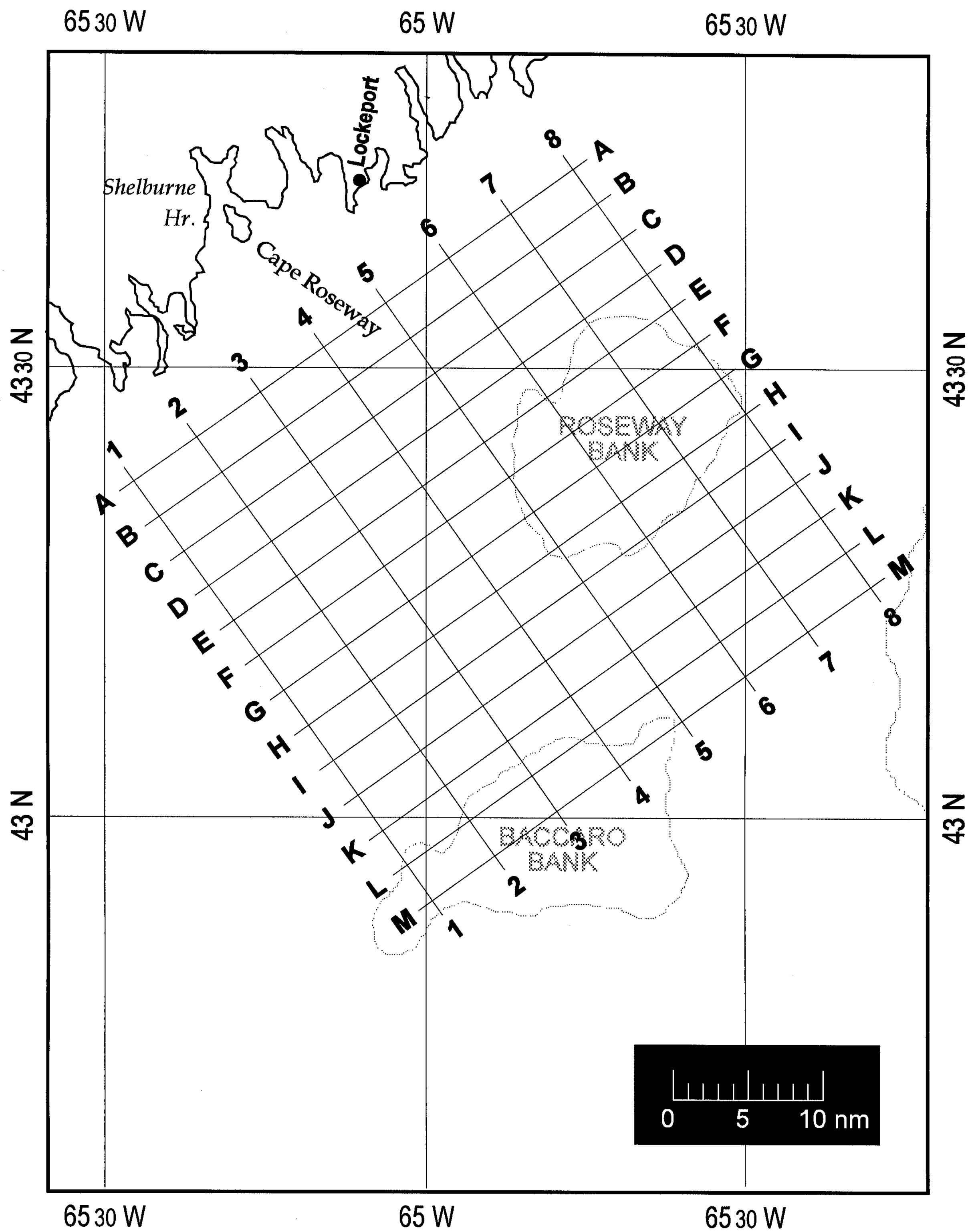


Figure 4.2: Operations Area

4.3 Description of Vessels and Experiment Equipment

4.3.1 Vessel Descriptions

Search Vessel

The CCGC "Bickerton" is a Coast Guard primary SAR vessel and is classified as a 300A SAR high endurance life boat. The following are the pertinent characteristics of the CCGC "Bickerton".

Length	16.0 m
Beam	5.2 m
Average Draft During Field Operations	1.5 m
Search Speed	15.0 kts
Endurance	20.0 hrs
Height of Eye on Monkey Island	7.3 m
Maximum Visual Detection Range from Monkey Island to Life Raft	6.1 nm
Height of Anemometer	9.2 m

Daylight visual searches were conducted from Monkey Island using two lookouts, one on either side (port and starboard). There were virtually no restrictions to vision caused by the superstructure.

Support Vessels

The field experiment was supported by the CCGS "Sir William Alexander". In addition to being used for deploying and recovering the SAR targets, the vessel was also used to carry out target maintenance and as a control centre for the experiment.

The CCGS "Sir William Alexander" is a Coast Guard buoy tender. The vessel length is 83 m with a beam of 16.3 m. The vessel has ample deck space and stowage facilities forward and was well suited for supporting the project. No problems were experienced in the deployment and recovery of SAR targets. This type of vessel would be well suited for supporting future experiments.

4.3.2 Experiment Equipment

SAR Targets

The SAR targets used during the validation trials were 4- and 6-person life rafts. Four life rafts were deployed for each search. The life rafts were deployed with and without sea anchors. The life rafts were outfitted with plywood floors for mounting equipment and each life raft was outfitted with nylon webbing lifting straps as well as floating tag lines to facilitate deployment and recovery. All life rafts were marked to identify them as being Coast Guard research targets.

Positioning and Tracking Systems

GPS

A GPS receiver and data logger was mounted in each life raft. GPS positions were logged every five (5) minutes and were used in target track reconstruction. The GPS data logger was stored in a waterproof pelican case mounted to the plywood floor inside the SAR target. The GPS receiver was mounted on an aluminum mast outside the canopy of the life raft. The mast was also secured to the floor. Additionally a GPS receiver and data logger were installed on the search vessel to record its track during each search.

ARGOS

An ARGOS transmitter was either mounted or attached to each life raft. ARGOS provided target positions on an average of ten (10) times per day. The primary purpose of the ARGOS positioning was to track the SAR targets. It also provided a backup to the GPS system in providing search track reconstruction. On a few occasions the data logger battery power expired and ARGOS positions were used to supplement GPS track data. For certain periods, approximately from 0000 - 0500 AST and 1200 - 1700 AST, ARGOS information was not being updated.

VHF Beacons

A VHF beacon was attached to each life raft. The beacons were used in conjunction with the ARGOS system for the tracking and recovery of targets.

Life Raft Lighting System

All life rafts were outfitted with white flashing lights mounted on the life raft mast. The lights operated on a photocell switch and therefore did not come on during the daytime and thus did not enhance the SAR target in terms of increasing the probability of detection. The purpose of the lights was to assist in the location of targets during recovery operations and also to alert other vessels of the targets' existence so that the targets were not run down.

Night Vision Goggles

Two (2) sets of NVGs were used on the support vessel. The NVGs were acquired on loan from the USCG, and were used for target location during after dark recovery operations of SAR targets.

Environmental Monitoring (Search Vessel)

The following environmental monitoring equipment was either installed or supplied by OCEANS Ltd. on the search vessel:

- 2 marine screens c/w dry and wet bulb thermometers;
- 1 sea bucket c/w sea thermometer;
- 1 hand held anemometer;
- 1 temporary anemometer system (supplied by USCG); and,
- Environmental logbooks.

Leeway Equipment

In order to collect leeway data during the field program, one of the life rafts was outfitted with the following extra equipment:

- 1 KVH compass unit;
- 1 CR10 data logger;
- 1 RM Young anemometer system;
- 1 air temperature sensor;
- 1 sea temperature sensor; and,
- 1 InterOcean S4 current meter (supplied by USCG).

4.4 Data Collection

4.4.1 Detection Data

Daylight visual searches were conducted on the CCGC "Bickerton" from the Monkey Island by two crewman, one on either side of the Monkey Island. A total of 4 lookouts were used and lookouts were rotated approximately every hour. Prior to the first search being undertaken, crew members were briefed on the experiment and what their roles were to be.

The CCGC "Bickerton" normally departed Shelburne at 0600 or 0700 and searches began at either 0800 or 0900 and lasted for 4 to 5 hours. The cruising speed of the CCGC "Bickerton" during the search was approximately 15 knots. In total six (6) searches were conducted. During searches 3,5 and 6 the life rafts were outfitted with sea anchors and during searches 1,2 and 4 the life rafts were deployed without sea anchors. The six searches are depicted in Figures 4.3 to 4.8.

Prior to beginning a search, the search coordinates were passed to the CCGC "Bickerton"; this usually occurred on the eve of the search. During each search an OCEANS Ltd. employee supervised the search and recorded detection and environmental data.

4.4.2 Environmental Data

Environmental observations were taken hourly from the search vessel. The following environmental parameters were observed and recorded routinely:

- prevailing visibility (nm);
- cloud cover (tenths);
- weather (rain, snow, fog etc.);
- dry bulb temperature ($^{\circ}$C);
- wet bulb temperature ($^{\circ}$C);
- ship's heading ($^{\circ}$ True);
- ship's speed (knots);
- apparent wind direction ($^{\circ}$ relative);
- apparent wind speed (knots);
- true wind direction ($^{\circ}$ True);
- true wind speed (knots);
- combined wave height (m) and period, seconds (s);
- estimated swell direction ($^{\circ}$ True); and,
- degree of white capping (none, some, or many).

SAR-94 Search Number 1

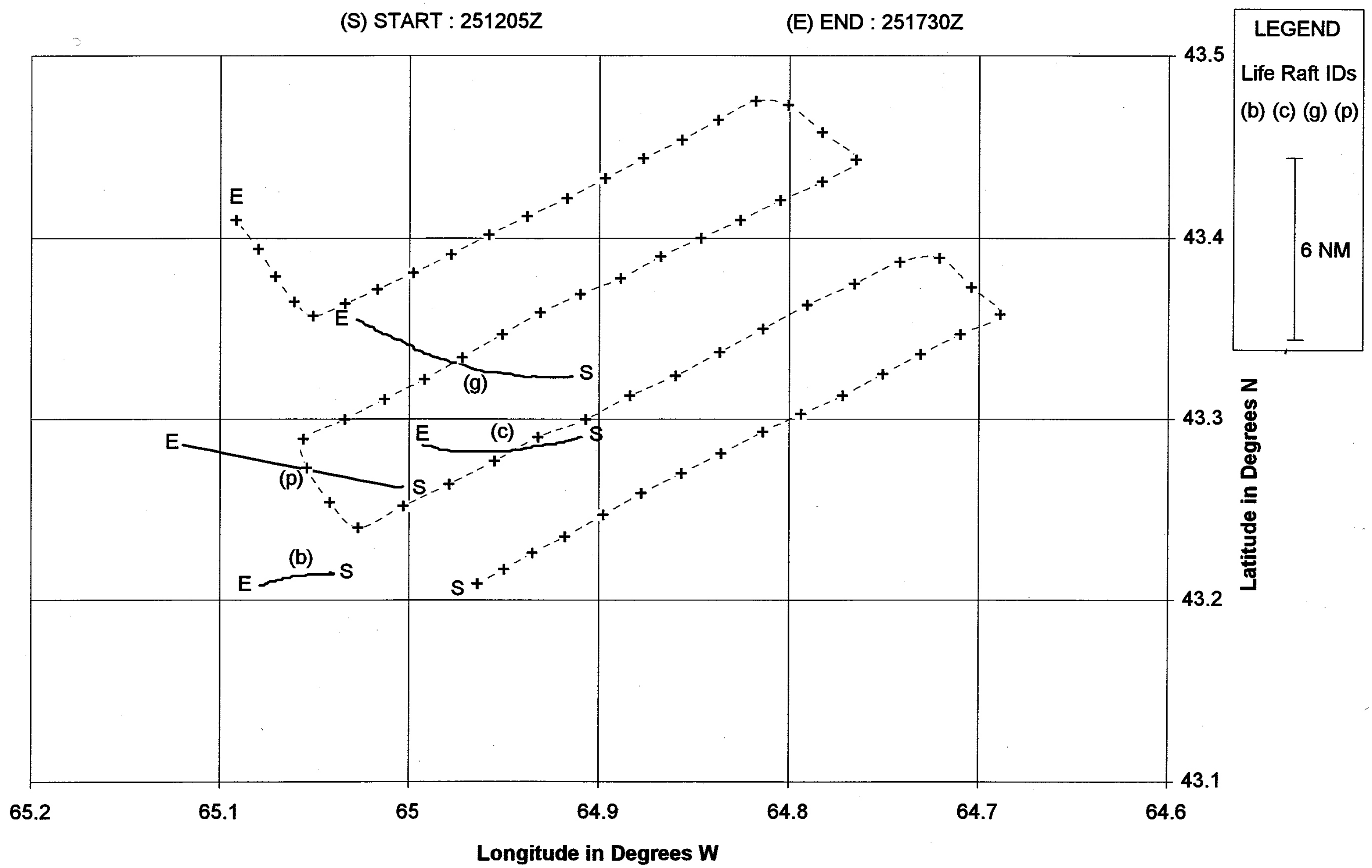


Figure 4.3

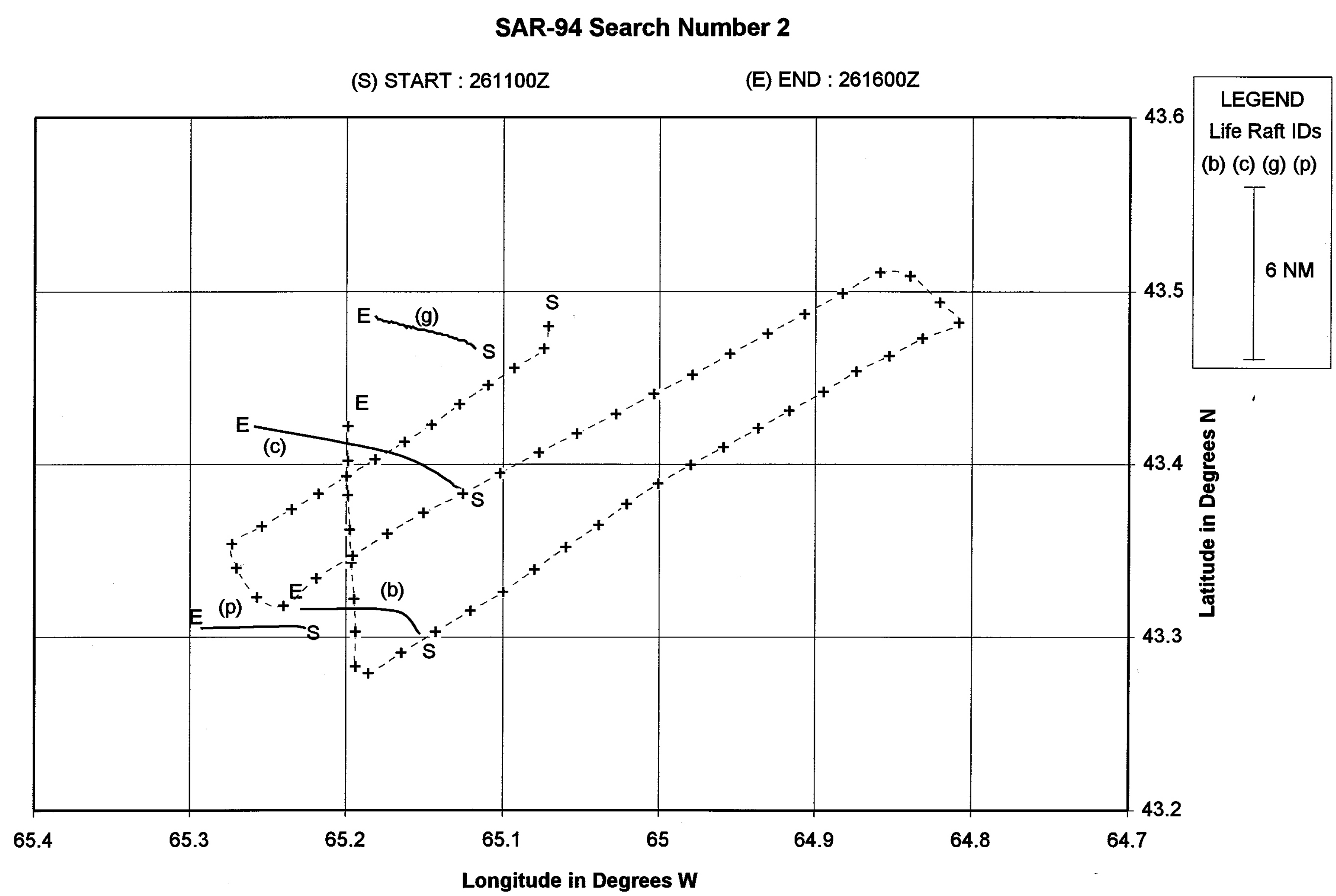
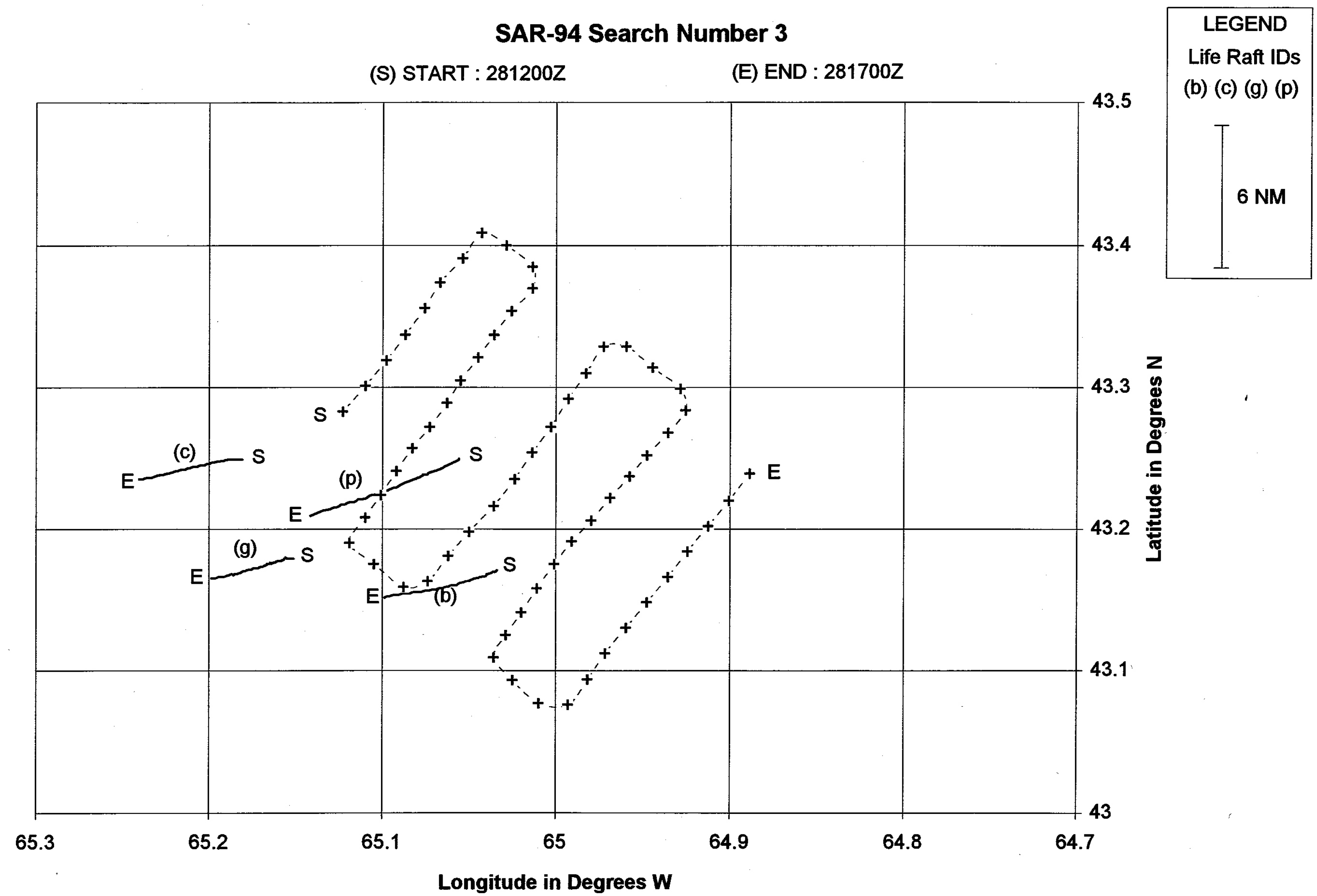
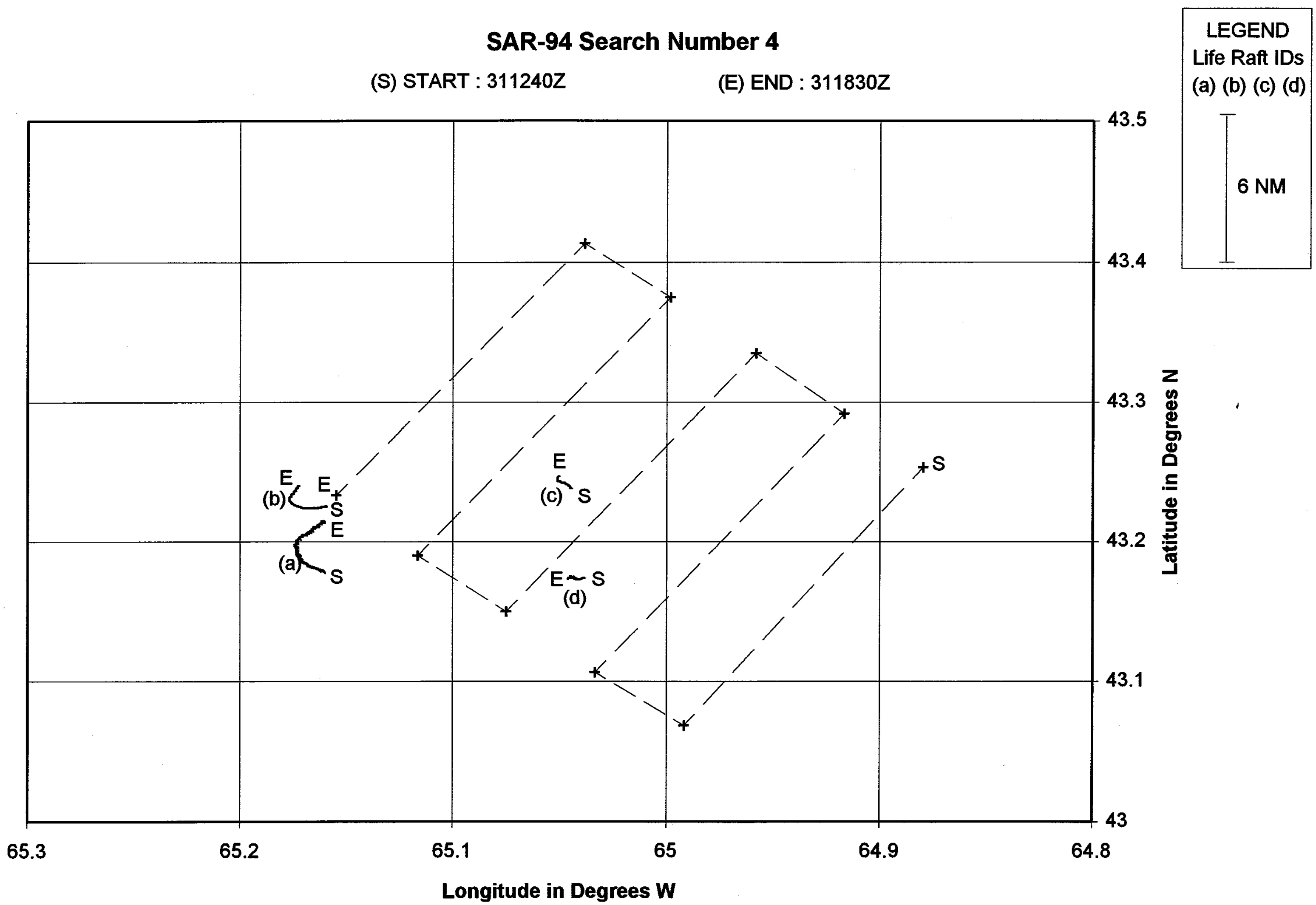

SAR-94 Search Number 2
(S) START : 261100Z
(E) END : 261600Z
LEGEND
Life Raft IDs
(b) (c) (g) (p)
6 NM
Latitude in Degrees N
Longitude in Degrees W
43.6
43.5
43.4
43.3
43.2
65.4
65.3
65.2
65.1
65
64.9
64.8
64.7
(b)
(c)
(g)
(p)
S
E

Figure 4.4



SAR-94 Search Number 3
(S) START : 281200Z
(E) END : 281700Z
LEGEND
Life Raft IDs
(b) (c) (g) (p)
6 NM
(c)
(p)
(g)
(b)
S
E
43.5
43.4
43.3
43.2
43.1
43
65.3
65.2
65.1
65
64.9
64.8
64.7
Longitude in Degrees W
Latitude in Degrees N

Figure 4.5



SAR-94 Search Number 4
(S) START : 311240Z
(E) END : 311830Z
LEGEND
Life Raft IDs
(a) (b) (c) (d)
6 NM
43.5
43.4
43.3
43.2
43.1
43
Latitude in Degrees N
65.3
65.2
65.1
65
64.9
64.8
Longitude in Degrees W
(a)
(b)
(c)
(d)
E
S

Figure 4.6

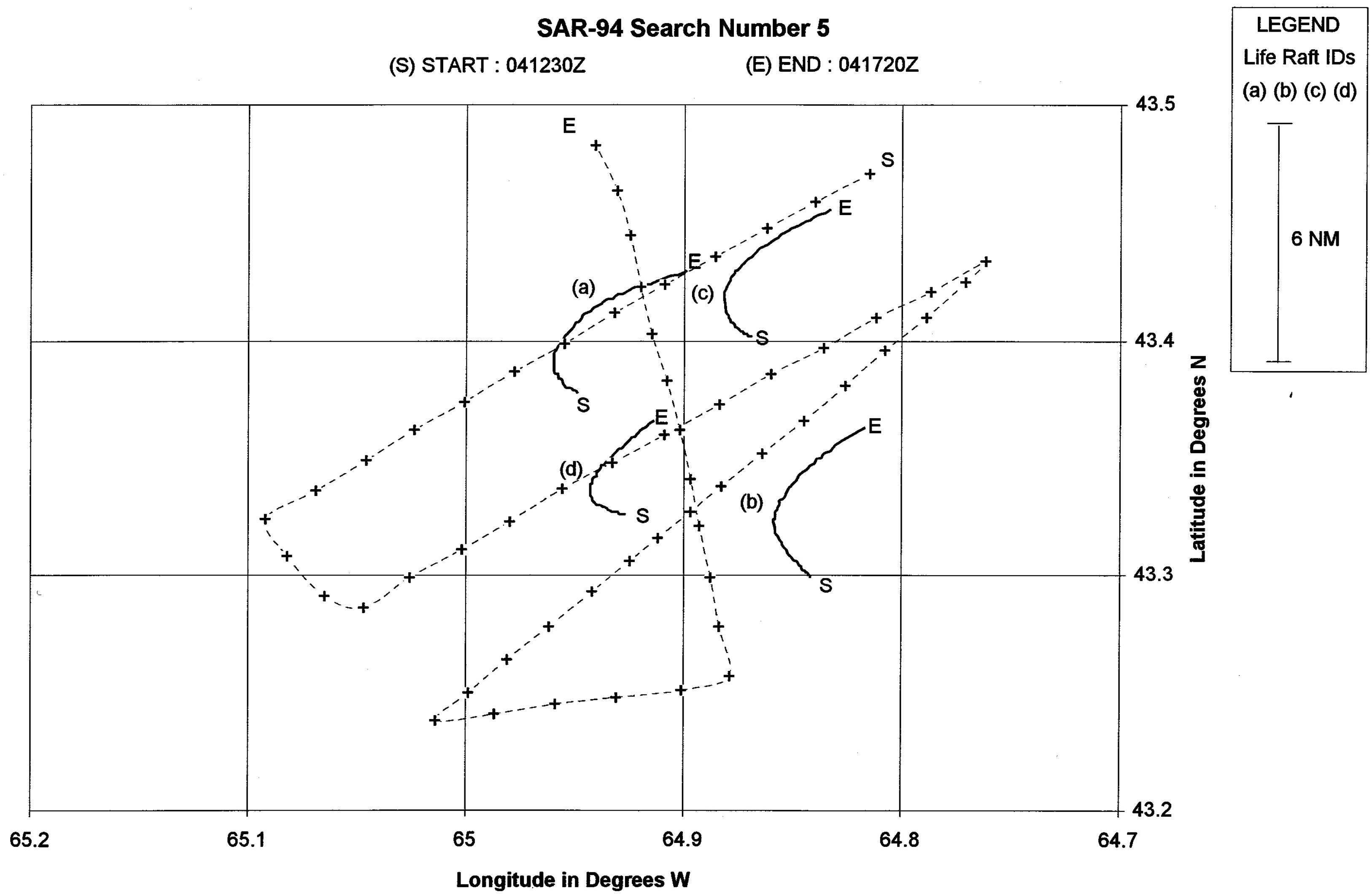

SAR-94 Search Number 5
(S) START : 041230Z
(E) END : 041720Z
LEGEND
Life Raft IDs
(a) (b) (c) (d)
6 NM
43.5
43.4
43.3
43.2
65.2
65.1
65
64.9
64.8
64.7
Longitude in Degrees W
Latitude in Degrees N
(a)
(b)
(c)
(d)
S
E

Figure 4.7

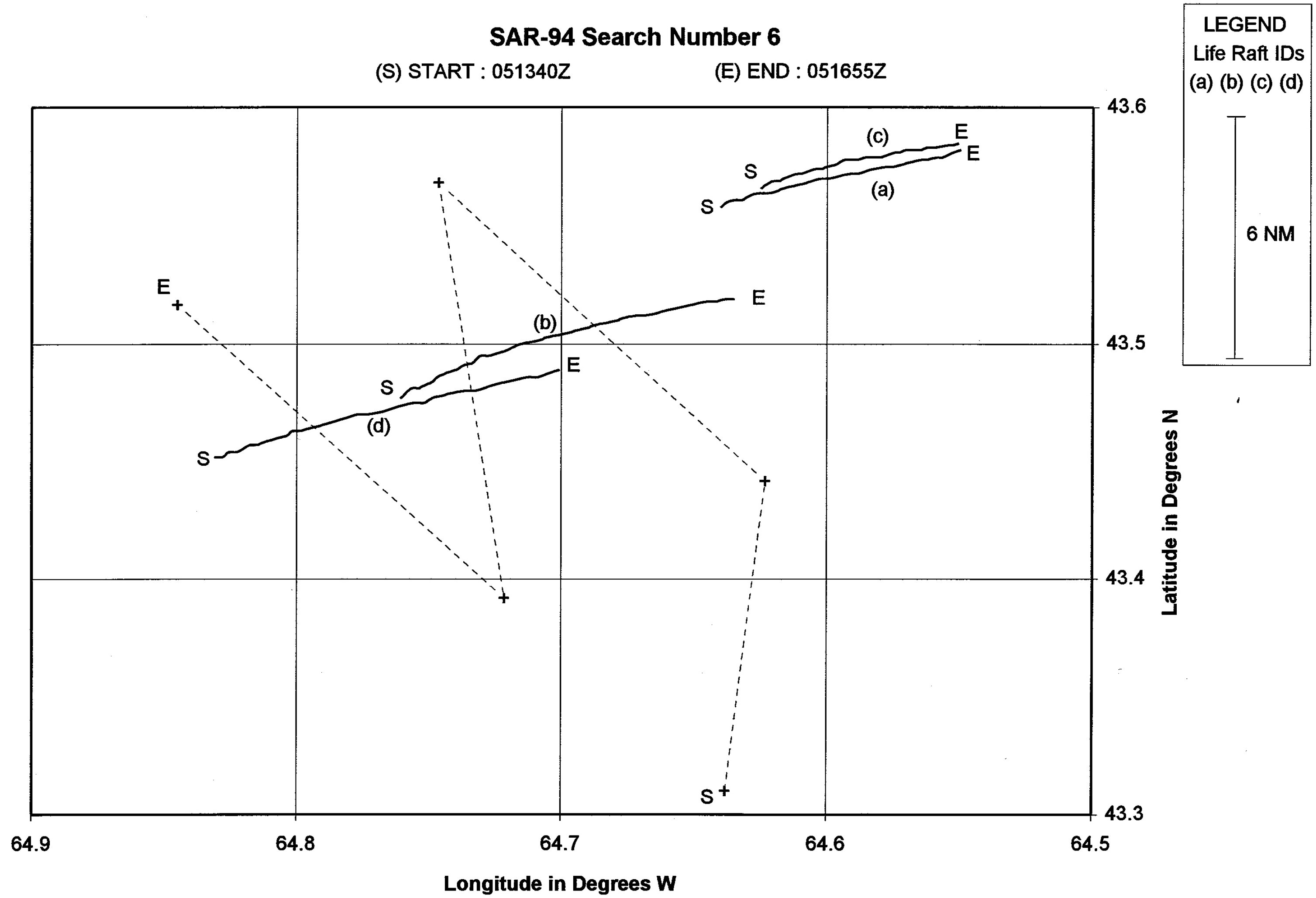

SAR-94 Search Number 6
(S) START : 051340Z
(E) END : 051655Z
LEGEND
Life Raft IDs
(a) (b) (c) (d)
6 NM
43.6
43.5
43.4
43.3
Latitude in Degrees N
64.9
64.8
64.7
64.6
64.5
Longitude in Degrees W
(a)
(b)
(c)
(d)
S
E

Figure 4.8

4.5 Validation Trial Results

The main objective of the validation trials was to assess the feasibility of conducting POD trials using drifting SAR targets and to assess the impact of collecting data for related SAR research.

To assess the use of drifting targets for use in POD trials, the CCGC "Bickerton" conducted searches for 4- and 6-person free drifting life rafts that were deployed in a defined operations area extending to approximately 50 nm off Shelburne, N.S. The life rafts were deployed both with and without sea anchors. To assess the impact of collecting data for related SAR research, leeway data was collected on one of the targets during the POD trials. The experiment was controlled and supported from the CCGS "Sir William Alexander".

As a result of the validation trials and subsequent review of the data the following observations can be made:

1. The support vessel for future major POD trials should be dedicated to the project.

   During the early stages of the project, the support vessel had to provide support for both the POD trials and a SAREX that was taking place in the Georges Bank and the Bay of Fundy area. The support vessel was able to perform the task but it is realized that if the POD trials had been a major experiment there no doubt would have been logistical complications.

2. A CCG base should be used as the operations base for future major POD trials.

   In future detection trials, especially those involving larger targets, a CCG base would offer the experiment extra stowage and maintenance facilities that would be required throughout the course of a major experiment.

3. For vessels whose offshore activity is restricted, data collection will be at a slower pace than for vessels with no restrictions.

   With search vessels having to remain near the coast, the operations area will be obviously restricted, thus the recovery of targets will be more frequent.

4. Data for vessels with small crews will be collected at a slower pace than that for vessels with larger crews.

5. For those targets tested, there appears to be no significant difference between the POD data collected using free drifting targets and that collected using moored targets.

Relative to the search vessel, the SAR targets are slow moving. During the data reduction of the validation trial data, there were no problems in establishing valid detection opportunities.

6. Drifting targets were found to maintain the same general arrangement throughout the searches.

7. Leeway data was collected on one SAR target without too much difficulty.

   To carry out leeway drift trials and collect data for other related research during the course of a major POD experiment, human resources will have to be carefully considered.

5.0 VALIDATION TRIAL DATA ANALYSIS

5.1 Introduction

The methodology employed for the analysis of the visual search data was the same as that used in the previous Canso Bank experiments (Fitzgerald et al., 1990) and followed USCG procedures for these types of experiments. It involved a multivariate regression technique to compute a relationship between various independent variables (regressors) and the probability of search object detection. In addition to lateral range, defined as the minimum distance between the position of the search object and the observer's track (often referred to as the closest point of approach (CPA)), relevant independent variables include physical attributes of the search object (for example, size and colour), observer parameters (for example, height of eye and time on task), and environmental conditions (for example, significant wave height and prevailing visibility). Sweep width, the resultant parameter used in actual search planning is determined by integrating the probability of detection with respect to lateral range for the relevant values of the significant independent variables. The concept of sweep width, as explained by Koopman (1980), is interpreted as follows: the probability of detecting a search object beyond one half the sweep width, on either side of the SAR vessel, is equal to the probability of missing a target located less than one half the sweep width on either side of the search unit. Figure 5.1 illustrates the concept of sweep width.

5.2 Data Reduction Methodology

The data reduction methodology involved the reconstruction of each search. Following the reconstruction of the tracks of the search vessel and targets, all the opportunities and detections were compiled for each search, and the relevant variables were assigned to each opportunity (for example, wind speed, wave height, visibility, etc.). Only those opportunities with lateral ranges of 6 nm or less were used in the analysis. The data was compiled on a computer system at OCEANS Ltd., where the analysis was performed.

5.3 Data Analysis Methodology

Multivariate logistic regression models have proven to be appropriate tools for fitting Coast Guard visual search data where the dependent variable is a discrete response (i.e., detection/no detection). The detection data from the daylight visual searches

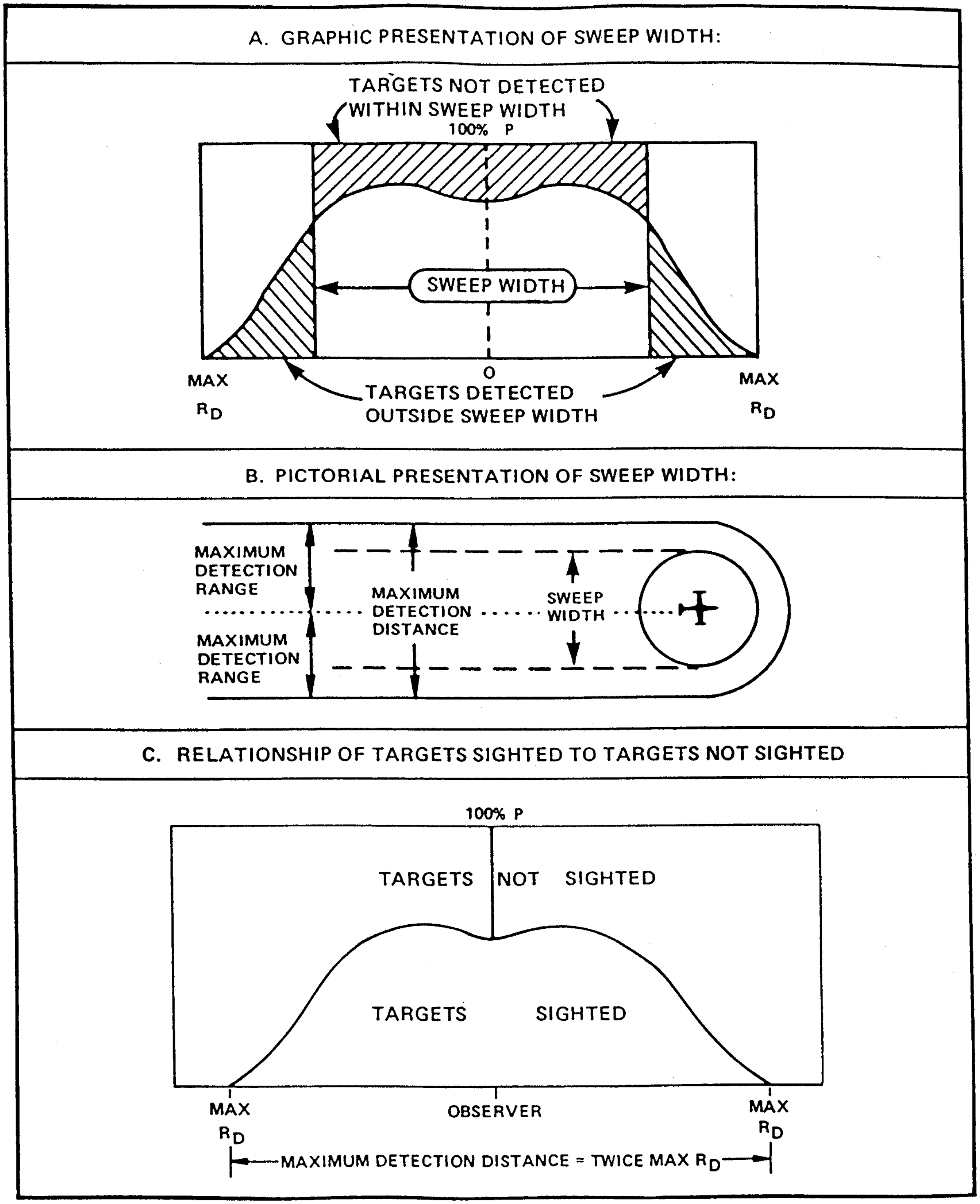


Figure 5.1: Concept of Sweep Width

conducted from the CCGC "Bickerton" were analyzed using a commercially available software package from SYSTAT, Inc. called LOGIT. This is the same software employed by the USCG in their data analysis. The LOGIT software uses the maximum log-likelihood technique to fit a logistic curve to response data that can be broken down into discrete categories. Results using LOGIT were confirmed against the results obtained using the maximum log likelihood model run on a DEC VAX 11/750 computer.

The maximum log likelihood model described by Cox (1970) is used to determine the probability of detection (P) as a function of a combination of a number of independent variables. The model uses the following equation:

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

where,

$$\lambda = a_o \sum_{i=1}^{n} a_i x_i$$

and,

a_o is a constant;
a_i is the coefficient of the ith independent variable;
x_i is the value of the ith independent variable; and,
n is the number of independent variables.

The independent variables may be discrete (for example, life raft colour) or continuous (for example, wind speed). The variables are preselected and checked for their statistical significance at the 90 percent confidence level in an interactive procedure. Those variables that are not significant at the 90 percent confidence level or whose limits at the 90 percent confidence level cross zero (or, in other words, one limit is positive and the other is negative) are rejected sequentially, starting with the one having the lowest significance. The multivariate regression analysis is repeated after each non-significant independent variable is removed until all the remaining variables contribute significantly to the variability of λ .

Having determined λ , the probability of detection, P, as a function of lateral range (x), can be determined for given values of the other significant independent variables. Sweep width (SW) is then computed using the relationship:

$$SW = 2 \int_0^{\infty} P(x)dx$$

5.4 Results

The data set for the CCGC "Bickerton" consisted of 70 valid target detection opportunities. The factors tested for significance included:

1. lateral range;
2. visibility;
3. cloud cover;
4. precipitation;
5. wind speed;
6. significant wave height;
7. white caps; and,
8. life raft size (4 or 6 person).

Table 5.1 provides a summary of the data set.

Table 5.1

Variable Listings
Daylight Visual Search

Bickerton - 70 Opportunities

	LR	VIS	CLD	PCP	WND	WVS	WC	SIZE
MIN	0.20	4.5	1.0	0.0	0.0	1.0	0.0	0.0
MAX	5.85	6.0	10.0	0.0	25.0	2.0	2.0	1.0
AVG	2.86	5.7	5.7	0.0	10.9	1.5	0.4	0.2

Legend:

LR - Lateral Range in nm	WND - Wind Speed in knots
VIS - Visibility in nm	WVS - Wave height in metres
CLD - Cloud cover in tenths	WC - White caps (0=none, 1=some, 2=many)
PCP - 0 = no precipitation - 1 = precipitation	SIZE - 0 = 4-person - 1 = 6-person

Table 5.2 presents the significant variables, regression coefficients and sweep width calculation for the daylight visual searches conducted by the CCGC "Bickerton" against 4- and 6-person life rafts as represented by the data set.

Table 5.2

Bickerton Monkey Island
Results

Significant Variables	Regression Coefficients
(Constant)	-5.2881
Lateral Range (lr)	-2.8024

Sweep Width Calculations:

For Average Conditions: Sweep Width = 4.6 NM

As seen from Table 5.2 lateral range was found to be the only significant variable. This is not unexpected since the data set is fairly small, all searches were conducted in relatively good weather and there was not a wide variation throughout the variables tested. Figure 5.2 shows the probability of detection curve based on the average conditions encountered.

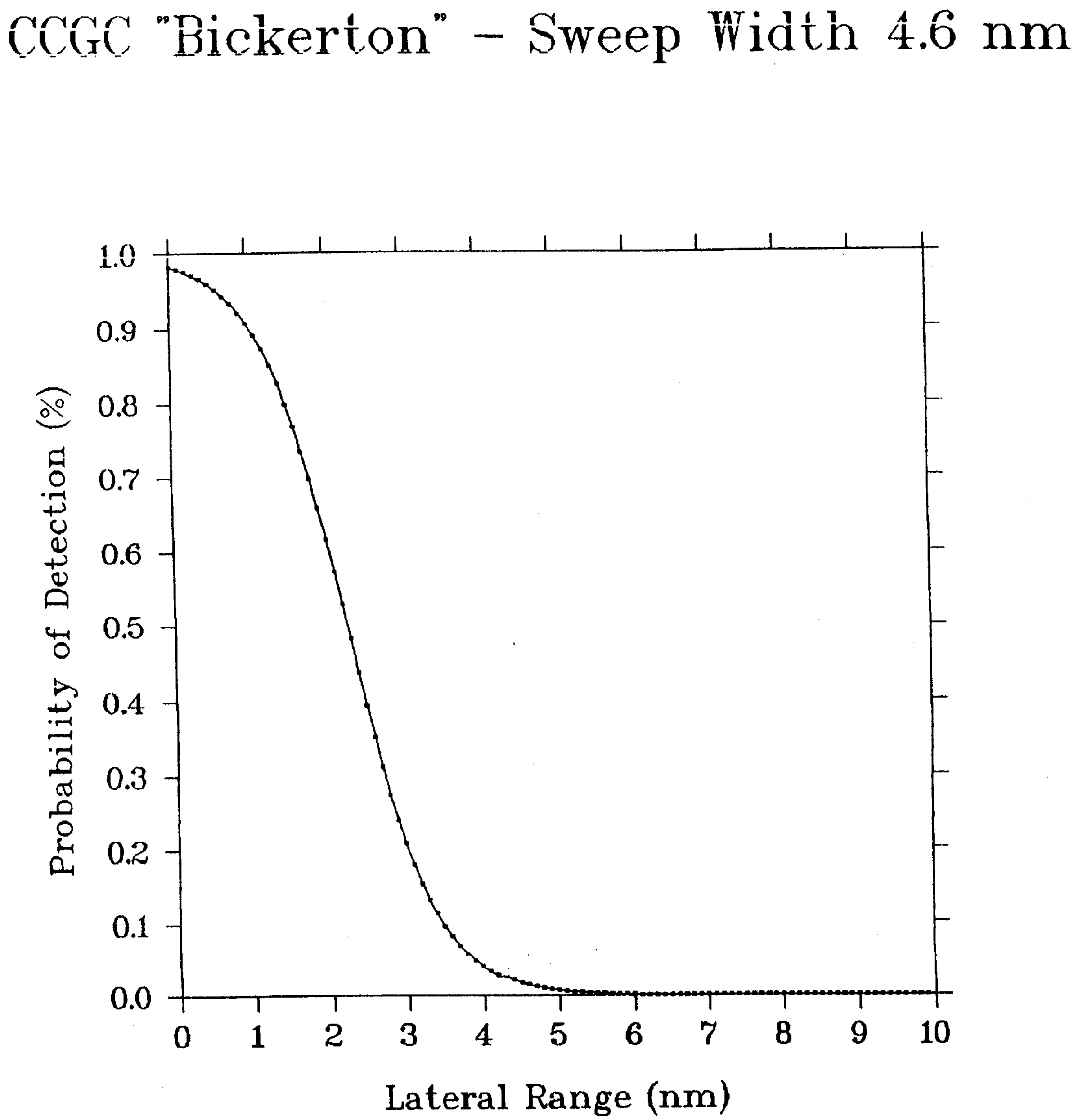

CCGC "Bickerton" - Sweep Width 4.6 nm
Probability of Detection (%)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
10
Lateral Range (nm)

Figure 5.2

6.0 EXPERIMENT PLAN

The following sub sections describe OCEANS Ltd. proposed Experiment Plan, which is intended to provide the framework for conducting future detection trials.

6.1 POD Data Collection Methodology

During the course of a detection experiment involving drifting targets, a variety of data will have to be routinely collected. These data relate to the independent variables to be tested for significance during POD analysis. Other supporting data will also be collected routinely. Inherent in the routine data collection will be data of value to related SAR projects. Table 4.1 presents a combined summary of the independent variable data that will be collected during day, night and radar searches conducted from a vessel.

Table 6.1
Combined Independent Variables

Target	SRU	Environmental	Ambient Light	Human Factors
Type Size Colour Illumination Radar Reflectivity	Speed Lookout Height Scanner Height Range Scale Heave Pitch Roll	Cloud Visibility Precipitation Wind Speed Wave Height White Caps Air Temp. Water Temp.	Relative Sun Azimuth Moon Elevation Moon Visibility Artificial Light Level.	Lookout Posn. Experience Time on Task

With the exception of wave height and in some cases vessel heave, pitch and roll, any sensors required to collect the above data are normally available on CCG vessels. Motion sensors and a wave monitoring system would have to be provided separately. This is discussed further in section 6.3.4 (Data Acquisition Systems).

Detailed, accurate and immediate recording of information related to events as they occur in the field is critical to efficient post exercise data reduction and analysis. Appendix "A" provides a sample of field recording logs that are recommended for POD experiments. Accompanying each log is a description as well as instructions on how entries should be recorded.

6.2 Experiment Management

To carry out a detection experiment from beginning to end essentially involves three phases: (1) the preparatory phase; (2) the field trials; and (3) the analysis. Since the analysis is to be done further along in the overall project, the experiment plan presented will deal primarily with the preparatory work and the field trials. Prior to the beginning of any field trials a field plan should be prepared and circulated among the participants. The following sub sections contain information on the important issues involved in the preparation and conduct of a SAR detection experiment, which will provide the framework for conducting future detection trials.

6.3 Phase I - Field Experiment Preparations

6.3.1 Vessel Requirements

A minimum of two vessels should be involved in the experiment. One being the search vessel and the other being the support vessel. As early as possible in the project these vessels should be tasked so that experiment planners will have a chance to visit the vessels. These visits are important because they allow the planners to evaluate the vessel in terms of facilities, instrumentation, equipment, stowage and so forth. Equally importantly, it allows the experiment personnel to discuss the upcoming field trials with the vessel's Captain and to obtain information with respect to the operational limitations of the vessel.

It is recommended that the support vessel be at least a 1000 class vessel. The vessel should have sufficient stowage area for the stowing and maintenance of selected SAR targets, and should be capable of recovering such targets in moderate sea and wind conditions. The requirements of the support vessel will be somewhat dependent on the type of targets to be tested. If boats up to 30 feet are to be tested then deck space will be very important, as well as deployment and recovery equipment.

The basic roles of the vessels taking part in an experiment will be as follows:

Search Vessel

- o Conduct searches for SAR targets as instructed.
- o Provide a work area for day to day activities of the experiment team; and,
- o Provide necessary communications to liaise with the support vessel.

Support Vessel

- o Deploy and recover SAR targets and ancillary equipment such as waveriders, drifter buoys and so forth;
- o Provide necessary facilities for stowage, maintenance and preparation of SAR targets and ancillary equipment;
- o Provide a work area for day to day planning of experiment search operations; and,
- o Provide necessary communications to liaise with the search vessel and to access positional information through the ARGOS network.

Other than SAR standby, it is strongly recommended that vessels be totally dedicated to the POD trials. Prior to the trials and in order to accommodate SAR targets, the cargo hold of the support vessel(s) should be as open as possible in order to allow for the stowage and maintenance of as many SAR targets as possible. To assist search planners in scheduling deployment and recovery operations, it should be clarified at the beginning of an exercise or pre-exercise meeting what the operating limitations are with respect to winds, waves and night time operations.

6.3.2 Experiment Area and Time Frame

The following points should be considered when selecting an area and time frame for conducting a POD detection experiment.

- o Proximity of the experiment area with respect to the operations area of the vessels participating in the trials.

This has implications with respect to crew changes and SAR emergencies for participating vessels. As well, smaller search vessels have restrictions as to how far offshore they can work.

- Proximity of the experiment area to a CCG base.

  Past leeway trials were conducted from the CCG base in St. John's and having the resources of the base available to the trials was very beneficial. A base of this type can provide extra storage and maintenance facilities as well as the overall logistic support inherent to the base.

- Proximity of the experiment area to the contractor's home base.

  In addition to the above, trials carried out in an area near the contractor's home base would result in a significant saving with respect to mobilization costs.

- The experiment should be conducted in a area and time frame when a minimal number of SAR emergencies are expected.

- The experiment area should be exposed to a range of environmental conditions.

  The time frame selected for the trials will affect the type and range of environmental conditions that can be expected. All past POD experiments have been conducted during the fall, when the environmental conditions can be quite variable.

- Water depths should be minimized where possible.

  A consideration here is any mooring costs, such as for waverider buoys, as well as the time and operational difficulty involved with the deployment and recovery of such moored instrumentation.

- A low traffic area should be chosen.

  This will reduce the likelihood of interference with the experiment and the risk of collision between a SAR object and a passing vessel.

- An area where shore lights are minimal should be chosen.

Shore lights often pose problems during nighttime searches and in the data reduction of the field data.

In addition to the points above, other factors will need to be considered when collecting data for related SAR projects. These include:

- o The current regime of an area;
- o The prevailing wind direction of an area; and,
- o The quantity and quality of historical data available for an area (drift, current, and so forth).

6.3.3 Target Acquisition and Preparation

For the purposes of this discussion we are assuming that the targets of interest for immediate experiments will be PIWs, life rafts and small boats. It has been proposed that POD models be developed for these targets in a variety of configurations. The configurations include:

- o Life rafts outfitted with retro reflective tape and with and without canopy lights;
- o Small white boats with and without radar reflectors; and,
- o PIWs wearing orange survival suits equipped with and without safety lights.

Only targets in good condition should be used. For boats and life rafts this is of particular concern. If targets become altered by losing air and by the canopy collapsing, in the case of a life raft, or shipping significant amounts of water, in the case of a life raft or boat, then the target cannot be classified as a valid detection opportunity. This adds extra work to the analysis process as well as extra work for field personnel trying to maintain such targets.

The preparation of large life rafts and boats for sea trials is a major task. The first requirement in the preparations is to have warehouse facilities large enough to house the targets and to be able to properly work on them. As mentioned previously, targets should be in good condition. Small boats in good condition can be purchased for prices ranging between $ 1000 and $ 1500 depending on the size of boat. A new 4-person life raft costs in the order of $ 2500 while a 20-person life raft is priced around $ 9000. Targets should be prepared at the contractor's warehouse. This will prevent any complications with respect to mounting sensors, attaching lifting arrangements and so forth.

If targets are to be outfitted with lights, reflective tape and radar reflectors, care must be taken to ensure that these items are as close to realism as possible. Lights should be of the same intensity as normally found on life rafts and survival suits while radar reflectors should be similar to types found on boats of similar size to those being tested.

In preparing targets it is extremely important to make them as seaworthy as possible without affecting the natural appearance of the target. Also it will be necessary to fabricate or otherwise acquire systems for housing and securing data collection systems. OCEANS Ltd. have always used waterproof Pelican Cases for housing data recording equipment and have found them to be of excellent quality. Life rafts should always be checked out by a survival craft repair service. Older life rafts whose canopies are severely faded should not be used. With respect to small boats, all leaks should be repaired and boats should be decked over to prevent swamping and also to protect data collection equipment. During past leeway trials larger targets were outfitted with small bilge pumps running off a 12 V marine battery. Immediately prior to any field trials, boats should be put in the water and let sit for a few days so that they can plim up. Life rafts and boats must be outfitted with lifting arrangements to facilitate the deployment and recovery of targets. Examples of such lifting arrangements are shown in Figure 6.1 (20-person life raft) and Figure 6.2 (Life Capsule).

During past leeway trials and during the validation trials associated with this project, life rafts were outfitted with wooden floors and these were used to house ballast and data collection systems. Meanwhile, boats were decked over and data collection systems and ballast were secured inside the boat. In addition to lifting arrangements, targets were also outfitted with tag lines to help control targets on deployment and recovery. These tag lines should be in the order of 10 m in length and should be floating type rope. This will allow for easy recovery of tag lines by the vessel during recovery operations.

All targets should be assigned their own ID letter. The ID should be clearly marked on the target. Also, all targets should be clearly marked as being part of a CCG experiment and notification information should also be provided. Larger SAR targets do pose a hazard to navigation, especially the rigid hull targets and they can also be the cause for a false SAR emergency. The liabilities regarding this issue are discussed in section 6.6.

20 Person Life Raft

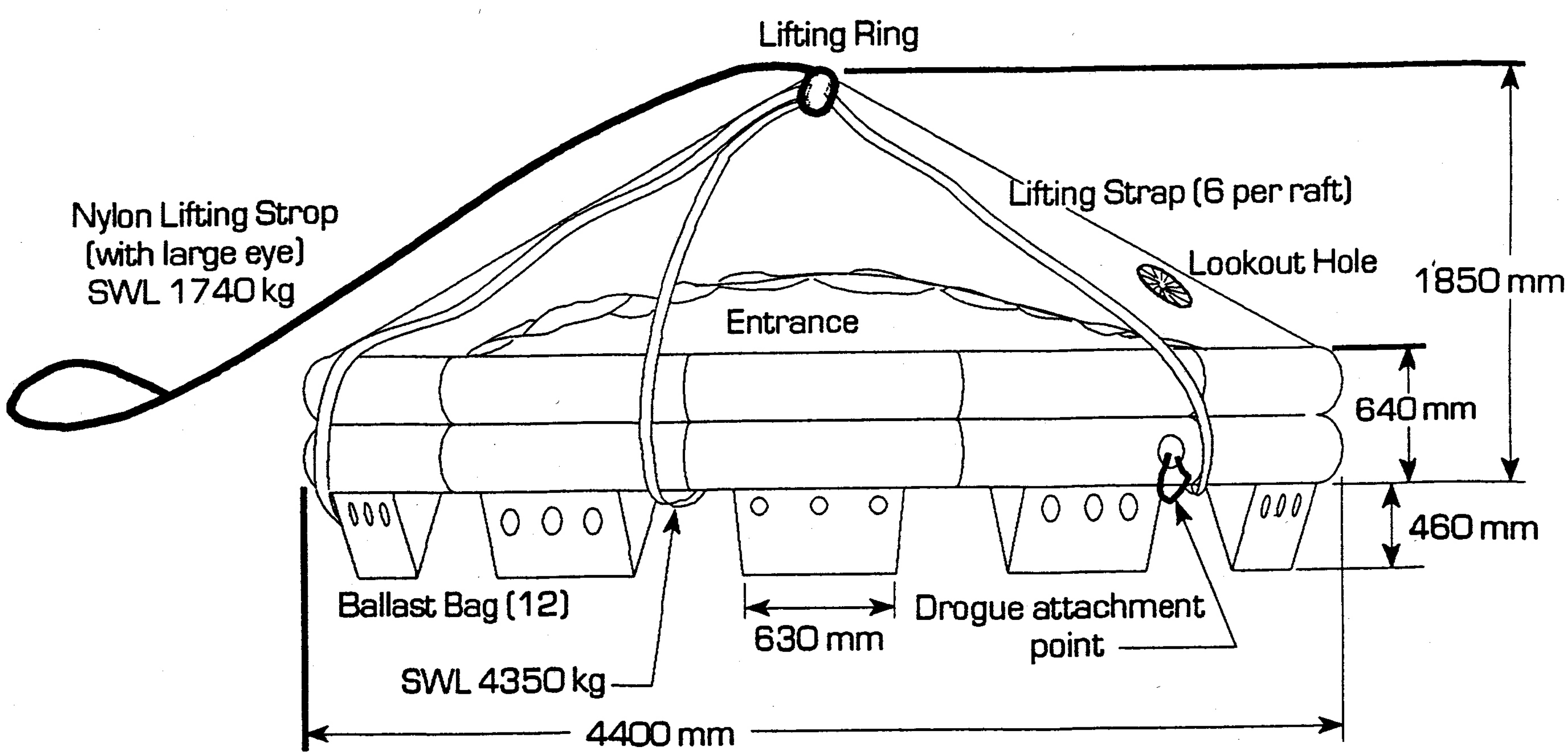


FIGURE 6.1

Life Capsule

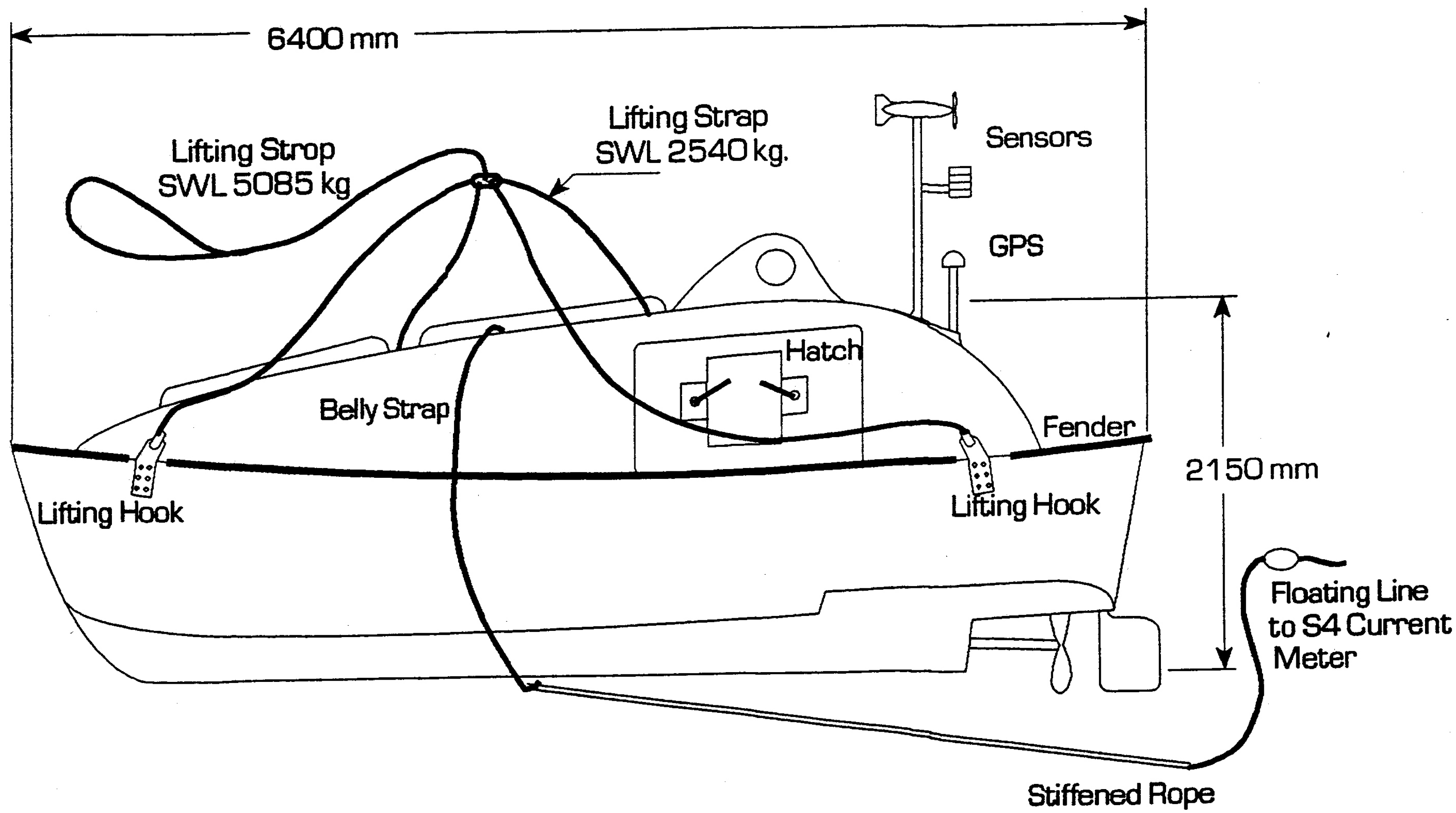


FIGURE 6.2

6.3.4 Instrumentation and Equipment

During past SAR detection experiments, with the exception of wave measurement, all required sensors were located on the search vessel. With the move toward drifting objects and the interest in collecting data for related SAR efforts, data will now have to be collected from the SAR target in addition to the search vessel. Data collection from the SAR target was done quite successfully during the leeway experiments conducted by OCEANS Ltd. For this discussion we assume that leeway data will be collected on some of the targets. Sensors required for data collection related to other SAR programs are addressed in section 6.5. The following outlines the instrumentation requirements for the search vessel and SAR target.

Search Vessel

- an anemometer system;
- dry and wet bulb thermometers housed in marine screens;
- sea thermometer c/w a sea bucket; and,
- a VHF direction finder.

Notes: 1. The direction finder is required to assist in the verification of targets during the experiment searches. As well, the direction finder will assist the search vessel in locating the targets if recovery operations are requested.

2. Arrangements should be made to have anemometers calibrated. If the search vessel is not equipped with an anemometer, arrangements should be made by Coast Guard to have one installed.

SAR Target

- an R.M. Young anemometer system;
- an air temperature sensor;
- a water temperature sensor;
- a flux-gate compass;
- a data logger;
- an InterOcean S4 current meter;
- a GPS receiver;
- an ARGOS Platform Transmitter Terminal (PTT); and,
- a NOVATECH VHF beacon.

Note (1): The ARGOS and VHF beacons are used for tracking and locating purposes and provide backup to the GPS for positional information.

Note (2): For the larger targets (20-person life rafts and boats) anemometer sensors should be positioned 3 metres above the water. S4 current meters should be attached to a floating tag line and positioned approximately .75 metres below the water surface.

Note (3): VHF beacons should all be on different frequencies. This will assist in target verification during the searches as well as help in the recovery of targets.

Note (4): With the exception of the S4 current meter, the cost of instrumenting a SAR target is in the order of $ 7500.

In addition to the above, the support vessel should have a VHF direction finder for tracking and locating SAR targets and a wave monitoring system(s) should be moored in a strategic location(s) within the operations area to collect wave data. The wave systems should have the ability to record wave data, because there will likely be times when the search vessel will be out of range of the wave buoy which normally transmits data over VHF.

The recommended frequency for recording environmental data onboard the search vessel is every hour unless there is a significant change in conditions, then recordings should be more frequent. Data onboard the SAR targets should be recorded at least every 10 minutes.

Outfitting PIWs with instrumentation requires further investigation. However, there should not be too much difficulty in outfitting the PIWs with an ARGOS transmitter and VHF beacon. This would provide basic position and tracking information.

It is very important that the data collected onboard the SAR targets be recovered. There are two ways to retrieve the data: directly from the data logging package, such as that developed by OCEANS Ltd., following the retrieval of targets; or by external methods such as VHF telemetry, Cellular modem or ARGOS. External methods carry a certain cost that would need to be evaluated against the project budget. During past leeway trials, data have been recovered by directly downloading the data from the data logging package on board the SAR target. During the leeway trials data loggers were always recovered. There was no data loss due to a damaged data logger, even though targets were left to drift for two to three days and in some cases capsized. This was a direct result of using state of the art logging systems and paying attention to the detail of housing and securing these loggers. During the trials external methods were not used to recover data.

Adequate size Gel Cell batteries should be used to provide the required power for the various sensors and loggers. During the leeway trials and validation trials, power was supplied from between 2 and 4 Gel Cell 12 V batteries. These batteries were 10 A/h and had to be recharged after every 2-3 days of usage. For future trials, the use of higher capacity Gel Cells is recommended. This will reduce battery maintenance, as well as offering more power security for the sensors and loggers.

6.4 Phase II - Field Experiment

Prior to commencing field trial operations, a notice to mariners must be sent that will outline the boundaries of the operations area and describe the targets that will be used during the trials.

6.4.1 Mobilization

The first step in the execution of the field experiment is the mobilization of equipment and personnel onboard the search and support vessels. For this discussion we are assuming the targets for experiment trials will consist of small boat (16'-30'), life rafts ranging from 4-person to 20-person and PIWs. The following are the main points to consider during mobilization:

1. Coordinating the mobilization of the vessels through CCG logistics personnel.

   Before equipment and personnel are mobilized onboard any vessel, close coordination will be required. During pre-field meetings the dates for mobilization of the vessels will have to be established. As the time draws near to mobilize, the contractor's project manager and the Coast Guard regional coordinator should stay in regular contact. Any delays in ship movement or other delays or alterations should be communicated as soon as possible. This is extremely important because delays can affect not only the contractor but also the many outside agencies and groups that usually need to be coordinated during experiments of this nature.

2. Transporting equipment and personnel to and from the experiment vessels.

   Equipment is normally transported to the vessels by truck. In terms of personnel, if the experiment is away from the contractor's home base, personnel will either travel via truck with the equipment or via commercial airlines. During the last major detection trials conducted in 1990 on the Canso Bank off Nova Scotia, the contractor supplied seven (7) personnel to the field trials. Two of the personnel travelled via truck with the equipment while the remainder travelled via commercial airlines.

If the experiment vessels are in the immediate vicinity of the contractor's home base then targets can be fully or partially outfitted and shipped by boom truck. In the case of life rafts they can be shipped to the vessel fully inflated, floors installed, anemometer masts mounted and so forth. If the targets are to be shipped to vessels not in the immediate vicinity, then in the case of life rafts, these would have to be deflated and outfitting would have to take place on the vessel or at facilities near the operating base of the field trials. The outfitting of life rafts takes considerable time and effort. As an example, during the validation trials it took two full days (14-16 hours per day) to fully outfit 6 small life rafts (4- and 6-person). The outfitting of six 20-person life rafts would take at least triple the time provided all else fell into place - facilities, weather and so forth. In the case of boats, the mobilization effort is similar. With the vessels in the immediate vicinity, boats can be shipped via boom truck and stowed either on the vessel or at a designated location in the immediate area. Shipping the boats out of the immediate area creates obvious problems.

If trials have to be conducted in an area away from the contractor's home base, shipping the large targets and, for that matter, all experiment equipment by vessel should be considered. As an example, if the trials were to be conducted in the Maritime Region and equipment and personnel were located in the Newfoundland Region, then a support vessel from the Maritime Region could come to St. John's where equipment and personnel could be placed onboard. She could then return to Maritime Region waters to rendezvous with the search vessel and the search vessel could be mobilized. The mobilization of the search vessel should normally take a day. Alternatively, a vessel from the Newfoundland Region could provide the support for the trials.

The following summarizes the above discussion in point form:

- conducting the experiment in the immediate vicinity of the contractor's home base is seen as the most efficient way to conduct the POD trials;

- if there is a requirement to have the trials take place away from the contractor's home base, then the transporting of equipment and personnel via vessel should be considered; and,

- if targets have to be outfitted during the mobilization stage, a longer period than normal should be allowed for mobilization.

6.4.2 Crew Meeting

Following the vessel mobilization it is important that a meeting take place with the crews of both the search vessel and the support vessel. The following issues should be addressed at such a meeting:

Search Vessel

- reason for the trials;
- how searches will be conducted;
- the roles of the lookouts and procedures for reporting;
- demonstration of the proper use of any sensors or equipment that lookouts or other personnel may be required to operate;
- details of individual testing, such as human factor related tests that may be carried out on individual lookouts and operators.

Allow for a question and answer period with the crew.

Support Vessel

- reason for the trials;
- role of the support vessel;
- demonstration by video of the deployment and recovery of SAR targets and ancillary equipment;
- support that may be required from time to time in the maintenance of SAR targets and ancillary equipment.

Allow for a question and answer period with the crew.

Note: Following the meeting and before departing for the sea trials, the contractor and crew should carry out a few dry runs in the harbour to familiarize everybody with deployment and recovery techniques. A dry run on recovery and deployment of a SAR target should also be performed at sea.

6.4.3 Communications and Time Standard

Prior to the beginning of the field trials, operation officers of each vessel should designate a VHF channel for intership communications as well working channels for any aircraft communications that may be necessary.

All data recording should be carried using the same time standard. Since all target positional information is automatically recorded in UTC time, the use of this time standard appears to be the most logical.

The operations area should be broken down into a grid and waypoints in the grid should be identified alphanumerically. Search tracks can then be communicated to the search vessel and any search aircraft. It is suggested that waypoints being communicated over radio be done using the phonetic alphabet to reduce the risk of any misunderstanding.

6.4.4 Target Deployment, Tracking and Recovery

The methodology suggested here is very similar to that employed during past leeway trials. The description that follows primarily describes the deployment, tracking and recovery of a SAR target (boat or life raft) involved in the collection of leeway data. However, the same basic philosophy can be applied to POD trials using other drifting objects and collecting related data for other SAR projects.

Once a deployment location is decided upon and weather conditions are deemed to be suitable for deployment, the vessel proceeds to that position while the SAR objects are being prepared. Typical preparation of a SAR object for deployment will involve setting up the data logger for collection of the wind data, which also involves confirming the correct operation of the compass and wind sensors. The GPS recording system is then initialized. At the same time, the current meter is programmed and secured in its frame. Following this the ARGOS transmitter is turned on and its operation confirmed. Following these instrumentation checks the line attaching the current meter to the SAR target is secured and if a sea anchor is required this will be attached to the current meter frame. Figure 6.3 shows a typical arrangement for a boat deployed during the leeway trials.

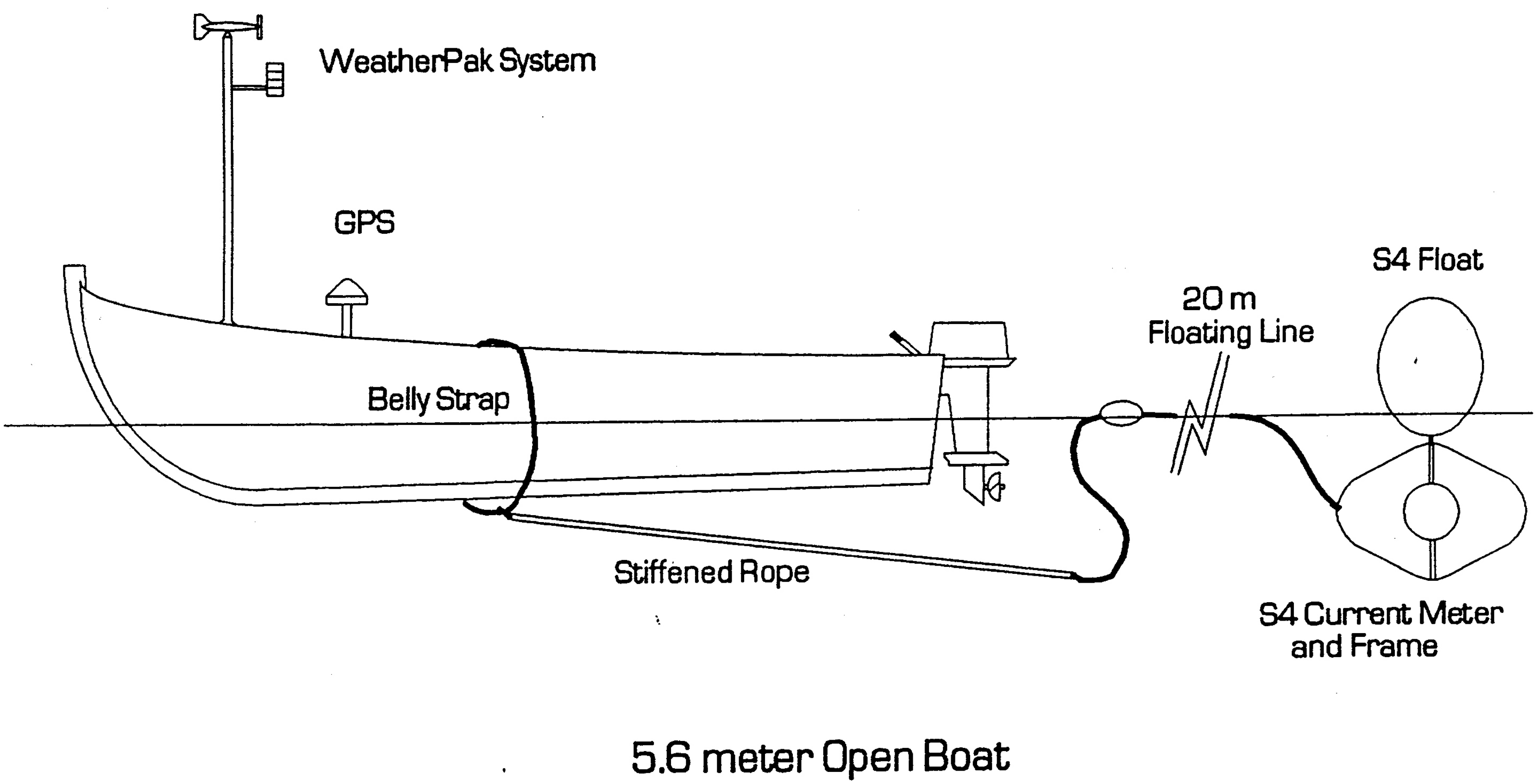


FIGURE 6.3: 5.6m Plank Boat

Prior to the deployment, the VHF transmitter, which should be spliced into the current meter tether, should be turned on and its operation confirmed through the ship's VHF direction finder. Following this, the SAR target can be deployed. First over the side will be the SAR target, which will be lowered using the ship's crane. Once the SAR target is in the water it will be allowed to drift away from the ship while the current meter tether is payed out. When the current meter is in the water, the drogue (if required) will be payed out in the same manner. Once all equipment is in the water and a positional fix is taken, the ship should move away so as not to disturb the natural drift of the SAR object. During POD trials the support vessel will leave the target array and either return to base or stand clear depending on the operational plan. While the support vessel is away from the area, positional information on the targets can be acquired through the ARGOS system. If the opportunity arises, the support vessel should carry out an inspection of the target array. The inspection should involve observing the general condition of the SAR targets, checking the trim of the targets, fouling of any lines and so forth. Videos of the drifting targets should be taken routinely and notes on visual observations should be routinely recorded in operational field logs.

When it is decided to recover the targets, the ship will proceed to the general location of the latest ARGOS position fix. Normally when the vessel arrives at this location it will already be picking up the VHF transmitter on the VHF direction finder. Once the VHF transmitter is picked up it will simply be a matter of steaming up to the target. An ARGOS direction finder belonging to the USCG has been used in past experiments for backup to the VHF transmitter/direction finder system.

During recovery, the SAR target should normally be approached from down wind. The first item to be retrieved will be the current meter tether. Once this line is onboard it will be used to bring the target alongside the rail while the current meter and sea anchor are brought onboard. While the target is alongside, all tag lines should be recovered and secured inboard. To bring the target onboard, a rope strop attached to a lifting ring on the SAR target is retrieved and attached to the lifting hook of the crane. Then the target is lifted onboard and secured accordingly.

SAR objects should always be deployed and recovered within the operating limits of the vessel. The recovery of a plank boat is more difficult than that of a rubber life raft primarily due to the fact that the boat is rigid and therefore more susceptible to damage. Also, an unmanned boat coming alongside a vessel, from observation, appears to be far more lively than a life raft. When recovering a boat, rubber bumpers (tires) should be deployed over the side of the recovery vessel and the conditions for recovery should be carefully considered. The best approach is to do the first recoveries in relatively low winds and seastates and then progress to recovering in higher winds and seastates that the vessel is comfortable with.

6.4.5 Target Array and Search Patterns

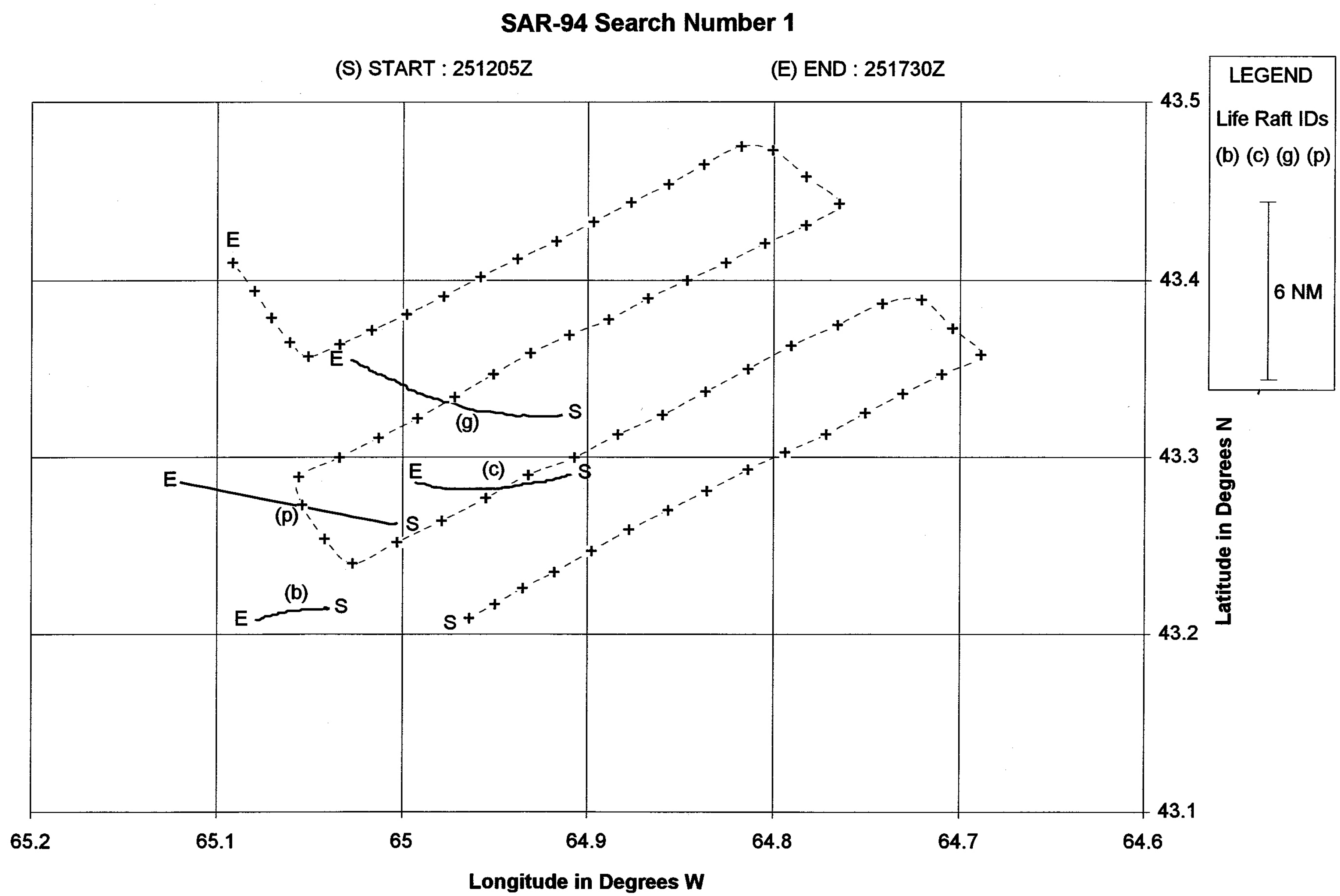
Figures 6.4 and 6.5 are provided as a reference for this sub section. Figure 6.4 shows the track of the first search conducted during the validation trials while Figure 6.5 shows the fifth search conducted during the trials. The dashed lines in each search represent the track of the search vessel while the solid lines represent the tracks of the SAR targets. The "S" represents the start of a track while the "E" represents the end of a track. The small letter in brackets associated with each solid line represents the target identifier.

Target Array

The over stimulation of SAR personnel by having too many targets in the target array must be considered. During the conduct of these experiments it has always been necessary to make them as realistic as possible. However, it would be impractical to go for days without seeing a target since the goal is to develop POD models which in turn means that opportunities for detecting targets have to be generated. In view of this, there needs to be an acceptable balance.

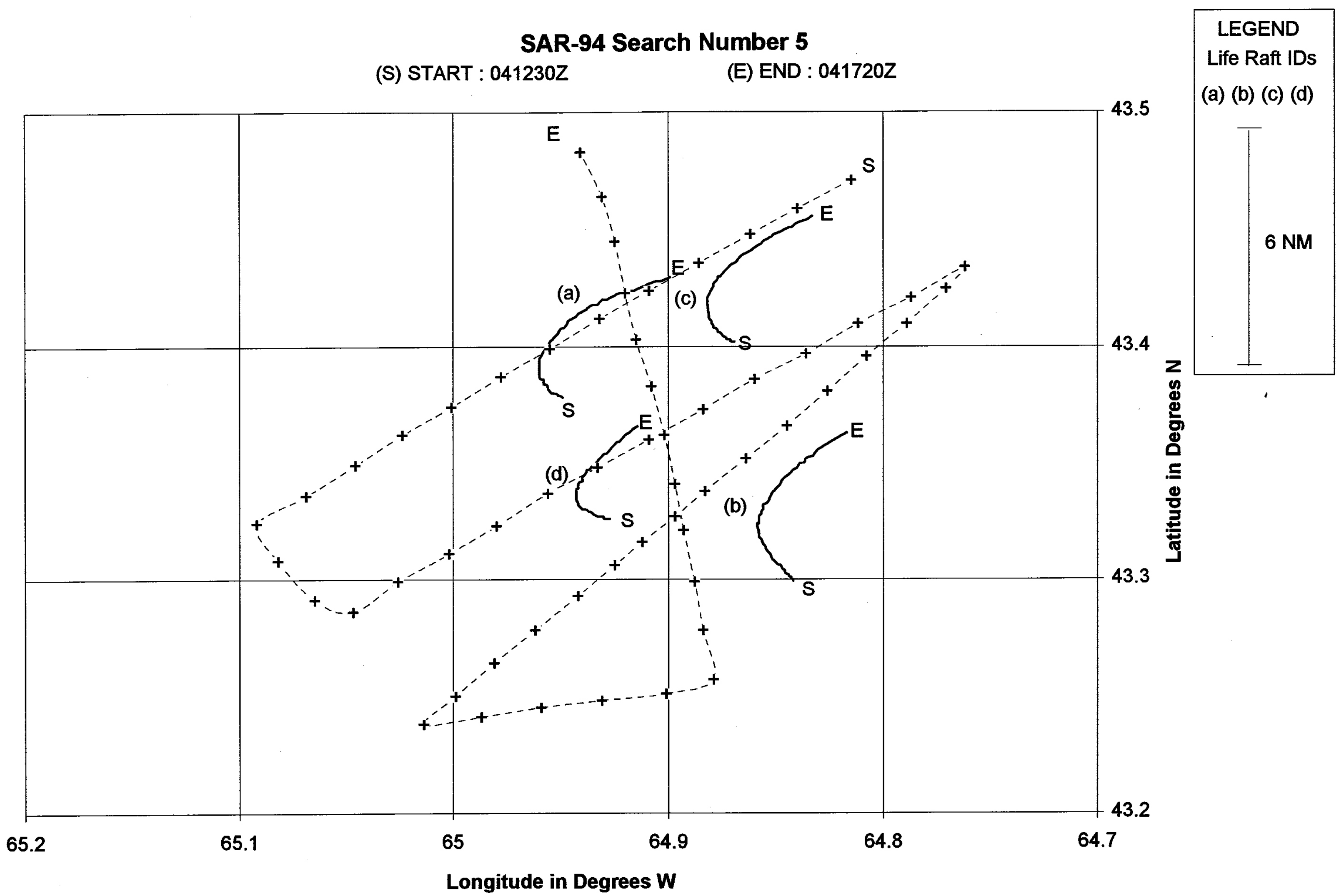
During the 1990 experiment there were 20 daylight targets at the beginning of the trials and they were deployed in an operations area of 450^2 nm. The intention was to generate as many target detection opportunities as practical without over stimulation of the lookouts. Targets were deployed in a random pattern throughout the operations area and were spaced no less than 3.5 nm apart. Search tracks were run from varying directions throughout the course of the experiment and this created target detection opportunities at random times and lateral ranges. The 20 targets used during the 1990 experiment appeared to be an adequate number and the maximum recommended for the size of the operations area.

In a drifting target array, the operations area would need to be expanded to a size similar to that used in past leeway trials, which was in the order of $8,100^2$ nm. Furthermore, the logistics of recovery for a drifting target array is more involved than it is with a moored target array. In view of this, up to 15 targets are recommended for an operations area of 100 nm x 80 nm using drifting targets. Initially, the targets should be deployed in a sub area within the operations area. The size of the sub area should be no smaller than that used in the 1990 experiment (450^2 nm). The area should be chosen with the intention of keeping the target



SAR-94 Search Number 1
(S) START : 251205Z
(E) END : 251730Z
LEGEND
Life Raft IDs
(b) (c) (g) (p)
6 NM
43.5
43.4
43.3
43.2
43.1
65.2
65.1
65
64.9
64.8
64.7
64.6
Longitude in Degrees W
Latitude in Degrees N
(g)
(c)
(p)
(b)
S
E

Figure 6.4



SAR-94 Search Number 5
(S) START : 041230Z
(E) END : 041720Z
LEGEND
Life Raft IDs
(a) (b) (c) (d)
6 NM
43.5
43.4
43.3
43.2
Latitude in Degrees N
65.2
65.1
65
64.9
64.8
64.7
Longitude in Degrees W
(a)
(b)
(c)
(d)
S
E

Figure 6.5

array within the main operations for up to 3 or 4 days if possible. To achieve this the planner will have to pay particular attention to forecasted wind conditions, tidal and sea current information if available, as well as making use of CANSARP guidance where possible. The initial target array pattern should be somewhat similar to that used in 1990, with the exception that target spacing should be not less than 5 nm. From past experiments it has been seen that an array of targets will generally follow the same general track at varying speeds. The spacing of targets on deployment may need to be adjusted periodically to keep them at a reasonable distance from each other.

Search Patterns

During past detection experiments two search patterns have normally been used. These patterns include the parallel search track (see Figure 6.4) and the angular search track or a combination of both (see Figure 6.5). Track spacing for parallel searches has ranged between 3 and 5 nm. Running the above search patterns from varying directions through the target array will generate detection opportunities at random times and lateral ranges. Track legs normally have been designed to last approximately 2 hours but can range from 1 to 3 hours depending on the speed of the search vessel and the target array spacing.

Search planners will have to plan search tracks so that opportunities are made available throughout the lateral range bins. Throughout the experiment, planners will have to evaluate which lateral range bins are being filled and where data may be lacking. In the preparation of search tracks, planners will have to make a prediction on how SAR targets will drift and then prepare search tracks accordingly. As an example, if detection opportunities are lacking in the lateral range bins from 4 - 6 nm then a search pattern should be designed that will generate a majority of opportunities across these lateral range bins during the search.

For the most part, search planners will not have up to date position information when preparing search tracks. The ARGOS network provides position information approximately 10 to 12 times per day. Therefore, planners will have to rely on position information that is a few hours old and to predict future drift on forecasted wind speeds, tidal and sea current if available and CANSARP guidance. As was discovered in the validation trials, the targets may not go exactly where one may expect them to go. Therefore, for the drifting objects, planning search activity for creating equal opportunities through the various lateral range bins will no doubt be somewhat crude until more experience is gained.

The effects of the above on the more visible targets, such as life rafts during daylight searches or lighted targets at night, will probably not be significant. However, for the less visible targets, the inaccuracy of predicted target locations during a planned search is of some concern. The sweep width for a PIW is going to be small, likely less than a mile. In order to develop POD models for this target, realistic opportunities between 0 and 2 nm will have to be made available. Therefore, the planner has to be a little more exact when planning the search. Presently it is not clear if this is possible. One approach to this potential data collection problem is to be prepared to anchor these targets if problems do arise.

Search Planning Scenario

It is intended here to give the reader further insight into the search planning strategy for a POD experiment using drifting targets by reviewing 2 searches carried out in the validation trials. In terms of acquiring target detection opportunities, the goal is to have a fairly equal distribution of opportunities in varying environmental conditions through the lateral range bins.

Each lateral range bin is equivalent to 1 nm and the lateral range bins are broken down as 0-1 nm, 1-2 nm, 2-3 nm and so forth. Similarly, environmental parameters are broken into bins. The following is an example of environmental binning:

	Bin 1	Bin 2	Bin 3
Wind	0 - 15	16 - 30	31 - 45
Waves	0 - 1 m	1 - 3 m	> 3 m
Visibility	0 - 2 nm	2 - 6 nm	> 6 nm

The lateral range bins extend out to the visual horizon of the search vessel. The visual horizon during a visual search is based on the height of eye of the lookout on the search vessel and the height of the SAR target above the water. The CCGC "Bickerton", the search vessel used in the validation trials, has a visual horizon of approximately 6 nm. Any targets whose lateral range was beyond 6 nm were not considered a valid opportunity. Similarly, any targets whose lateral range was beyond the prevailing visibility were not considered a valid opportunity.

Figure 6.4 shows the track of the first search conducted during the validation trials. This particular search was conducted during the daytime and lasted 5 hrs. 25 min. Track spacing during the search was approximately 3 nm with the longer search legs running approximately 20 nm. The speed of the search vessel during the search was approximately 15 knots. During the course of the search the total drift of the targets in the array ranged from 3 nm to 7 nm.

The first search consisted of 4 long legs and associated short turning legs. During each long leg 4 opportunities were generated for a total of 16 opportunities for the entire search. The number of valid opportunities resulting from this search was 14. One opportunity was disqualified for being beyond the visual horizon of the search vessel while the other was disqualified because after being detected on one leg it remained visible until the lateral range was passed on the following leg. The breakdown of valid opportunities and environmental conditions for the first search was as follows:

Bin 0-1	Bin 1-2	Bin 2-3	Bin 3-4	Bin 4-5	Bin 5-6
4	1	2	2	3	2

Environmental conditions:		
	Visibility	Good
	Cloud	3 - 10 tenths
	Wind	10 knots
	Waves	1 m

Figure 6.5 shows the track of the fifth search conducted during the validation trials. This particular search was conducted during the daytime and lasted 4 hrs. 50 min. The search pattern was a combination of parallel and angular search tracks. The speed of the search vessel was again approximately 15 knots. During the course of the search the total drift of the targets in the array ranged from 3 nm to 6 nm.

This search consisted of 4 long legs and 2 turning legs. During each long leg 4 opportunities were generated for a total of 16 opportunities for the entire search. The number of valid opportunities resulting from this search was 15. One opportunity was disqualified for being beyond the visual horizon of the search vessel. The breakdown of valid opportunities and environmental conditions for the fifth search was as follows:

Bin 0-1	Bin 1-2	Bin 2-3	Bin 3-4	Bin 4-5	Bin 5-6
4	1	4	5	0	1

Environmental conditions:		
	Visibility	Good
	Cloud	2 - 10 tenths
	Wind	$<$ 10 knots
	Waves	1-2 m

If the above two searches were conducted sequentially, for a subsequent third search, providing environmental conditions remained essentially the same, the planner would want to concentrate on generating detection opportunities in the lateral range bins 1-2, 4-5 and 5-6.

6.4.6 Target Transportation and Stowage

As the size of the targets increases, the logistics of stowage and transportation will be an issue for consideration. For future trials, large life rafts and 16' to 30' boats are some of the targets recommended. If objects such as these are used, the open deck space and hold stowage must be a consideration in choosing a support vessel. If a combination of large life rafts and boats are chosen for the target array, then it may be necessary to involve a second vessel for support or have one support vessel deploy the targets over a period of a number of days, if it is not capable of transporting all the targets. As a reference and based on observation, a vessel the size of the CCGS "Sir William Alexander" would be capable of stowing approximately eight (8) inflated 20-person life rafts on deck and possibly three (3) in the hold. The CCGS "Sir Humphrey Gilbert" would be capable of stowing possibly four (4) 20-person life rafts on deck and three (3) in the hold. These numbers represent maximums and on some vessels there may be a problem with targets stowed too far forward or aft, depending on whether the crane is stepped forward or aft; the problem being that the inclination of the boom may be of concern, especially when lifting heavier objects with a sea running.

6.4.7 Search Activity

With larger vessels capable of remaining at sea for an extended period, search activity should be carried out using two search periods of 8 hours duration each. The first search should be a daylight visual search beginning at 0800 and running until 1600. This has the search beginning following breakfast and ending before dinner. During the daylight search it may be also possible to conduct a radar search depending on whether a slave radar display is located somewhere other than the bridge.

Night searches should begin no earlier than one half hour after sunset and again should run for 8 hours. During night searches it may be possible to conduct radar searches from the bridge, however there is a possibility that visual lookouts could influence radar operators and vice versa. If there is a requirement to conduct radar and visual searches simultaneously from the bridge then the reporting protocol will have to be strictly adhered to so that one search does not influence the other.

Search activity should continue for 3 to 4 days with a break of 2 days in between. Providing the weather does not intervene in a major way, the above timetable should allow search personnel to remain relatively enthusiastic, and uninterrupted data sets can be collected for related SAR projects. After 3 to 4 days it is quite likely that targets will start to drift out of the operations area or require servicing. During the 2 day break in search activity, the support vessel can recover the targets, download collected data and refurbish the targets.

For smaller vessels that are restricted to near shore, the search activity will obviously have to be cut back. The search activity will have to be planned around the size of the crew, the endurance of the vessel and the operations area. As an example, the operations area during the validation trials extended to 50 nm offshore. Any wind from the south pushed the targets toward shore. On a couple of occasions search activity had to be curtailed to recover life rafts before they went ashore. Similarly, a crew of 5 persons cannot conduct an effective search program for as long as the crew of a larger vessel.

6.4.8 Human Resource Requirements

Contractor Personnel

Search Vessel

During a POD experiment involving larger SAR vessels, where search activity is carried on a 16 hour a day basis (two 8 hour search periods), a minimum of four personnel should be used to oversee the trials. Each search period would be covered by two personnel. The roles of the personnel would be to record and verify sightings, maintain the detection sensors as required (NVGs, radar recording systems, etc.) and observe and record environmental data. Obviously, with smaller restricted vessels, fewer personnel would be required to oversee the data collection.

Support Vessel

During the leeway trials conducted on the Grand Banks during 1992 and 1993 four personnel were required to conduct the trials. The basic role of the field personnel during these trials was to plan deployments of targets and buoys, maintain the targets, sensors and ancillary equipment, and check data quality. During the trials, which lasted in the order of 28 days, targets were in the water collecting data for approximately 50 percent of the time - as expected for these types of trials, which are normally conducted during the fall.

The support required for POD experiments involving drifting targets and the collection of data related to other SAR research will likely be the same order of magnitude as the requirements for the leeway trials.

Transport Canada Personnel

It is recommended that a representative from the Coast Guard SAR R & D Group be onboard during the trials. It is important to get first hand knowledge of how these trials are carried out and this person should also be a liaison between the contractor and the ship's senior personnel. Additionally the TDC project officer or representative should attend a portion of the trials also, to get first hand knowledge on how they are conducted.

Extra personnel may also be required to perform lookout and radar operator duties during the POD experiment. Ship's Captains are always conscious of the fatigue factor of personnel and of the need to respond in the event of a real SAR emergency. Extra lookouts and radar operators may alleviate this problem.

6.5 Data for Related SAR Projects

This sub section discusses the data collection requests for related SAR projects (see section 3.7). The following presents the requests in point form with a discussion on how the data can be collected or the task performed.

DATA REQUESTS FOR RELATED SAR PROJECTS

Fleet Technology

- o Wave spectra over reasonable periods, updated at least hourly.

Wave data for the above can be gathered through a standard waverider buoy which is available at OCEANS Ltd. or a minimet buoy which may be available from the USCG, who have expressed an interest in participating in these trials. Real time data is transmitted by VHF link and a receiving station will have to be installed on the search vessel. In order to get real time data, the search vessel will have to be within VHF range of the waverider buoy.

USCG

- o An emphasis on target types bigger than life rafts, perhaps small fishing boats and disabled sail boats.

For future experiments and for the fall trials, OCEANS Ltd. has recommended that small boats be included in the target array.

- o Seed the search area with drifter buoys in order to check the drift data, to conduct an experiment with satellite imagery, and also to evaluate the function of the buoys.

Similar activity was carried out during the 1993 leeway trials. The deployment of drifter buoys presented no problem; however, the recovery can be difficult in that the drifters are difficult to locate and, depending on the number of drifters to be recovered and area to be covered, the process of recovery could take some time. This would strictly be a role of the support vessel and deployment and recovery of the drifters would have to be planned around POD operations.

- o Emphasize the human factors involved with SAR. Issues such as training, experience, and fatigue should be quantified for visual and electronic observers.

This issue is also part of the recommendations put forward for the fall 1995 trials. Transport Canada should contract a human factors expert, as in 1990, to design a program to assess the above issues. This expert would be expected to participate in the field trials and could draw on the assistance of OCEANS personnel in the administering of any required tests and to collect required field data. Following the field trials OCEANS Ltd. would make available lookout information and performance data as required for the human factors analysis.

- o Check the adequacy of available environmental data bases.

Wind data can be collected at the SAR targets and the wind provided for use in the CANSARP/CASP programs can be verified against actual wind collected at the target. The minimet buoys are also capable of wind recording, and a current meter could be suspended from the buoy to measure near surface current - another input for the CANSARP/CASP program. Here again a comparison can be made.

Canadian Coast Guard

- o Specify the period and angle of roll and pitch and include the accelerations measured at the lookout position.

OCEANS Ltd. has recommended that these parameters be included in the variables to be tested for significance in the analysis of POD data. The instrumentation for collecting the information may be available on some vessels. If the instrumentation is not available onboard, then Fleet Technology may be able to install the instrumentation as part of their vessel motion investigation. Otherwise, OCEANS Ltd. may be able to supply a motion sensor system. Early investigations show the cost for leasing such a system to be in the order of $ 6000 per month.

- With respect to lookout information provide the following:

  - fitness measurements of each individual;
  - experience in lookout duties;
  - full report of his/her daily activities; and,
  - effectiveness of NVGs if used.

Certain lookout information that can easily be collected such as time on watch and experience are again recommended as variables to be tested for significance in future trials. However, an indepth human factors study should be designed by an expert and treated somewhat separately from data collected for POD analysis. As stated previously OCEANs Ltd. can provide support to such a Human Factors program.

- With respect to the drift error study provide the following:

  - Position: Latitude and longitude, Time (UTC) of each search target;
  - wind direction and speed at each target position or closest vessel's true wind direction and speed with her position; and,
  - water temperature, pressure, and depth at each search target's position or water temperature and pressure measurements measured as close as possible to the target's position.

All the above parameters can be measured at the SAR target. The only parameter that OCEANS Ltd. has not measured during past leeway trials has been pressure. Depending on the accuracy required, a pressure sensor can be installed on the target and pressure data can be recorded using a CR10 data logger or pressure can be obtained by interpolating the mean sea level pressure from Atmospheric Environment Service surface weather analysis charts. These charts can be acquired through the OCEANS Ltd. Weather Forecasting Office.

<u>Transportation Development Centre</u>

- Information on life raft configuration including:

  - inflated condition; and,
  - loading and position of ballast bags.

The above data is normally recorded in field logs on a routine basis.

- Barometric pressure measurements.

Same as discussed above.

- Detailed weather conditions of the previous 24 hours.

Wind, air and water temperature as well as pressure can be collected at the target. Wave data can be provided by a minimet buoy recording wave data at a central location in the operations area. Supporting meteorological data can be provided through the OCEANS Ltd. Weather Forecasting Office.

- Comparison of the target drift with CANSARP prediction.

Positional information will be acquired for each SAR target. GPS data will be recorded every 5 minutes. This data will be available for use for in comparison of target drift data with CANSARP predictions.

<u>OCEANS Ltd.</u>

- Collect leeway data on as many SAR objects as practical, especially small boats.

The USCG have expressed an interest in participating in the trials, especially during the collection of leeway. The USCG may be able to supply two (2) minimet buoys, two (2) WEATHERPAK systems which collect wind,temperature and pressure data, and a number of S4 current meters which are essential for the collection of leeway data.

- RCC should be involved in the planning strategy of search tracks with respect to CANSARP so that search results can be used by the CCG in the evaluation of CANSARP generated search patterns.

During the preparations for the fall 1995 field trials Coast Guard should work with OCEANS Ltd. to design a program whereby CANSARP generated search patterns can be used in some of the POD trial searches. The data detection results, target locations and ancillary data can be supplied to Coast Guard following the trials for input into the CANSARP Search Pattern Evaluation.

6.6 Other Issues

The Advantages of Conducting a "Double Blind" Trial

During past detection experiments personnel conducting the experiments were, for the most part, aware of target locations while the searches were being conducted. Every effort was made not to influence the lookouts as to the location of any targets. However, the actions of any one of the personnel overseeing the search activity may have influenced a lookout at some time during a search. If the detection experiment is controlled from a support vessel then the likelihood of influencing the lookouts is significantly reduced. Therefore, when feasible, experiment searches should be carried out in a "Double Blind" format.

Target Drift of at least One Tide Cycle (12 hours)

The need to have target drift over a period of one tide cycle is not seen as mandatory in the collection of POD data. However, for related SAR efforts such as the evaluation of CANSARP/CASP this factor is seen to be very important. As was seen from the validation trials, tidal current has a definite impact on the drift direction and speed of 4- and 6-person life rafts. This impact would be expected to vary from region to region dependent on the strength of the tidal current. During a detection experiment involving drifting targets it would be expected that targets would be left to drift in the order of two to three days, which would provide a good data set for drift evaluation and comparison to CANSARP/CASP.

Project Liabilities

The use of drifting targets creates obvious liabilities in that unmanned drifting targets, especially rigid hull targets (boats), present a hazard to shipping. In the contract for the fall 1995 trials, the legal position of TDC and CCG should be stated regarding this matter.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 General

1. The support vessel for future major POD trials should be dedicated to the project.

2. A CCG base should be used as the operations base for future major POD trials.

3. For vessels whose offshore activity is restricted, data collection will be slower than for vessels with relatively no restrictions.

4. Data collection for vessels with small crews will be slower than for vessels with larger crews.

5. For those targets tested (4- and 6-person life rafts), there appears to be no significant difference between the POD data collected using free drifting targets and that collected using moored targets.

6. Drifting targets were found to maintain the same general arrangement relative to each other throughout the validation trials searches.

7. To collect data for related SAR projects (e.g., leeway) adequate human resources must be available.

8. The target focus for future POD trials should be PIWs, life rafts and small boats.

9. The sensor focus for future POD trials should be visual, NVGs, radar and promising emerging technologies.

10. The platform focus for future POD trials should be CCG vessels, CCG fixed and rotary wind aircraft, DND fixed and rotary wing aircraft, Fisheries & Oceans vessels and surveillance aircraft and other suitable government agency aircraft.

11. The early focus in future POD trials with respect to targets should be targets configured for a worst case scenario (no lights or radar reflectors).

12. The early focus in future POD trials with respect to CCG vessels should be primary SAR vessels for which data already exists (300 and 600 class) and the 1100 class vessel for which data already exists.

13. In using drifting targets special attention will be required in the collection of POD data for low visibility targets such as PIWs in terms of planning search tracks.

14. The cost of completely outfitting a SAR target for POD trials and the collection for related data is a consideration when planning the size of the target array.

7.2 Recommendations for Fall 1995 Experiment

1. Augment the NVG data set for 600 Class Vessels searching for life rafts outfitted with retro reflective tape.

2. Begin collecting the data set for 600 Class Vessels conducting night visual searches for life rafts with retro reflective tape.

3. Begin collecting the data set for 600 Class Vessels conducting daytime visual searches for small white boats.

4. Begin collecting the data for 600 Class Vessels conducting daytime visual searches for PIWs wearing orange survival suits.

5. Begin collecting the data set for 600 Class Vessels conducting radar searches for small boats without radar reflectors.

6. Begin collecting the data set for 600 Class Vessels conducting radar searches for small boats with radar reflectors.

7. Carry out searches using the TITAN system.

8. Carry out searches using data fusion (TITAN - FLIR/LLLTV).

9. Invite CCRS to conduct searches using the Convair 580 using C band SAR against life rafts outfitted in the same way as those in the Canso Bank 1990 experiment.

10. Invite DND to participate in the search experiment using their search aircraft.

11. Continue the investigation of human factors involved with SAR specifically in the areas of training, experience, and fatigue for visual and electronic observers.

12. As part of the 1995 project, review the USCG detection data in detail and update the data requirements of the Canadian Coast Guard marine SAR resources as appropriate.

13. As part of the 1995 project, develop a software package that will assist in the experiment search planning for drifting targets.

The 600 class vessel has been recommended as the search vessel for SAR 1995 because a good deal of data has already been collected from this type of vessel and the vessel is classed as a primary SAR vessel capable of operating in all weather. Targets have been chosen based on worst case scenarios such as life rafts with retro reflective tape only, boats without radar reflectors and so forth.

For a complete listing of recommendations with respect to POD data collection please refer to section 3.

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APPENDIX " A "

POD EXPERIMENT FIELD LOGS

Table of Contents

List of Figures

1.0 DATA RECORDING LOGS

1.1 Target Particulars Log

The Target Particulars Log shown in Figure A-1 is used to list all of the SAR targets used during a field experiment. Target information is normally documented during field mobilization. The instructions for completing this form are as follows:

(a) Target ID - Each target is identified by an upper case letter painted on the outside of the target. This ID letter will be entered in the first column.

(b) Target Manufacturers and Serial Number - In the next two columns will be recorded the name of the manufacturers and the manufacturers serial number.

(c) Size - Record the size of the target.

(d) Shape - Record the shape of the target at its water plane.

(e) Color - Denote the color of the target.

(f) Remarks - Use this column to comment on any additional features of the target.

1.2 Target Status Log

Knowing the status of the SAR targets is very important for the post field data reduction in determining if a target was a valid opportunity. A Target Status Log is shown in Figure A-2. On deployment and recovery of the targets or when doing a sail by inspection, the status of the targets should be noted. The log is to be completed according to the following instructions:

(a) Top Matter - Record in this space the name of the support ship or SRU.

(b) Date and Local Time - In the first two columns record the dates and times of target deployment, inspection and recovery.

(c) Target ID - Enter the identifying letter of the target that is deployed, recovered or inspected.

(d) Operation - Enter "D" for deployment "R" for recovery and "I" for a sail pass inspection.

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TARGET PARTICULARS LOG

Target ID	Man.	Ser. No.	Size	Shape	Color	Remarks

Figure A-1

OCEANS Limited

TARGET STATUS LOG

Date	UTC Time	Target ID	Operation (D/R/I)	Remarks	Observer

Figure A-2

(e) Lighting - Enter in this column "ON" for illuminated, "OFF" for unilluminated and "?" for cannot be determined.

(f) Remarks - The observer must use this column to record any information on the condition of the target which may assist in the data reduction.

An example of typical comments that should be recorded are as follows:

- raft fully inflated;
- raft not fully inflated;
- canopy torn;
- door open;
- canopy collapsed;
- water shipped;
- color fading;
- target overturned;
- target icing.

1.3 Equipment Maintenance Log

In conjunction with the regular inspection and recording of target status, maintenance on the targets and ancillary equipment will be carried out onboard the support vessel. A maintenance history should be kept in a hardcover log book. The following is sample of maintenance items which would require particular attention and should be recorded:

- target structures;
- lighting systems;
- batteries;
- data loggers;
- positioning systems;
- tracking systems;
- temperature sensors;
- lifting straps; and,
- lines, shackles and so forth.

1.4 Environmental Data Log

Observations should be recorded hourly and whenever a significant change is noted. The Environmental Data Log is shown in Figure A-3 and is to be completed by an experiment team member on the search vessel according to the following instructions.

(a) Hour - Enter UTC time of each observation.

(b) VIS - Record the estimated prevailing visibility in nautical miles. If there is a large variance in visibility with detection enter the ranges and sectors in the remarks column.

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ENVIRONMENTAL DATA LOG

Date:________________

Search:______________

SRU:_________________

Time	Vis	CCld	Wx	Dt	Wt	Wnd	Wvs	Swell	WC	Heave	Pitch	Roll	Remarks	Obs

Figure A-3

(c) Wx - Record the conditions of weather and obstruction to vision such as rain, drizzle, snow, fog, haze, freezing spray, etc. Note the intensity as light, moderate or heavy.

(d) Cloud Cover - Record the fraction of the sky in tenths covered by clouds of all types. Any comments on the density of the cloud cover should be made in the remarks columns.

(e) TEMP - Record wet and dry bulb temperature in degrees celsius to the nearest tenth of a degree taken on the windward side.

(f) True Wind - Enter the calculated true wind speed and direction..

(h) COMB SEA - Enter the estimated significant wave height in metres and its period in seconds.

(i) SWELL - Enter the estimated direction of the predominant swell.

(j) W.C. - Report the extent of the white caps (none: N, some: S, many: M).

(i) Heave - Record the vessel heave in metres.

(j) Pitch & Roll - Record the half amplitude of both the roll and pitch in degrees and their periods in seconds over the amplitude of motion.

(k) REMARKS - Report any information related to the local environment or vessel response which may assist in the data reduction and analysis such as heavy spray, icing, background color and lighting, heavy or light overcast, violent rolling and pitching, etc.

1.5 Lookout/Operator Information Form

This log is to be used to keep track of the rotation and cumulative search time for the lookouts or radar operators during each search. The Lookout/Operator Information Log shown in Figure A-4 is to be completed according to the following instructions:

(a) Heading Information - Enter the date, the name of the SRU, the search type, and the search number.

(b) UTC Time - Record the UTC time that each lookout goes on watch and when he changes lookout location.

(c) Name and ID - Record the name and ID of each lookout.

(d) Location - Record the level (B for bridge and MI for Monkey Island) and the side (P for port and S for starboard) at which each lookout is posted.

OCEANS Ltd. **Date:**____________

LOOKOUT/OPERATOR INFORMATIION LOG

Search:____________

SRU:____________

Time UTC	Name	ID	Level (M/Mi)	Side (P/S)	Acc Time (hh/mm)	Remarks

Figure A-4

(e) Acc Time per L/O - At the end of each search enter in this column the time accumulated by each lookout during the search.

(f) Remarks - Record any comments.

1.6 Visual Detection Log

This log is to be completed by a data recorder on the search vessel to record sightings reported by lookouts along with information that will assist in the data reduction and analysis. Immediately after recording the sighting data, the recorder should make a best effort to confirm whether or not the sighting is one of the SAR targets. The Visual Detection Log shown in Figure A-5 should be completed according to the following instructions.

(a) Top Matter - Record the sequential search number, the date, start time and end time of the search, the name of the SRU, and the type of search.

(b) Sighting No. - Reported sightings should be numbered sequentially from the beginning of each search.

(c) Sighting/Turn Time - Enter the times of reported sightings and course alterations.

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VISUAL DETECTION LOG

Search #:__________ **Search Type:**____________ **SRU:**____________ **Date:**____________

Start Time:______________ **End Time:**________________ **Duration:**______________

No.	Sighting /turn time	Rng	Rel Brg	Shp Hdg	L/O Loc.	L/O ID	Remarks	Obs

Figure A-5

(d) Range - Enter the target range in nautical miles. The lookout will report his best estimate of range in nautical miles or in divisions of the distance from the ship to the horizon.

(e) Relative Bearing - Record the bearing of the sighting in degrees relative to the ships head.

(f) Heading - Record the compass heading of the SRU.

(g) Lookout Location and ID - Record the level (B for bridge or MI for Monkey Island) and the side (P for port and S for starboard) at which the lookout is posted and his identification letter.

(h) Remarks - Record any comments which may assist in the data reduction and analyses. The following is a sample of some of the items that may be included in the remarks.

- description of reported target
- visibility
- weather (fog, drizzle, rain, snow)
- target background colour and lighting
- density of cloud cover

1.7 Radar Detection Log

This form is to be completed by the radar observer on the search vessel to record radar detections. The Radar Detection Log shown in Figure A-6 should be completed according to the following instructions.

(a) Top Matter - Record the sequential search number, the radar unit, the SRU, date, start time and end time of the search and the duration of the search.

(b) Detection No. - Reported detections should be numbered sequentially from the beginning of each search.

(c) Detection/Turn Time - Enter the times of reported detections and course alterations.

(d) Range - Enter the target range in nautical miles.

(e) True Bearing - Record the bearing of the target in degrees true.

(f) Heading - Record the true heading of the SRU.

(g) Pulse Length - Record the radar pulse length.

(h) Range Setting - Record the radar range setting.

(i) Remarks - Record any comments which may assist in the data reduction and analyses.

(j) Operator ID - Record the operators identification letter.

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RADAR DETECTION LOG

Search #:__________ Radar Unit:__________ SRU:__________ Date:__________

Start Time:__________ End Time:__________ Duration:__________

Det. No.	Detection/ turn time	Rng	True Brg	Ship Hdg	Pulse Length	Range Setting	Remarks	Obs

Figure A-6

APPENDIX " B "

SAR '94 LEEWAY REPORT

TABLE OF CONTENTS

List of Figures:

List of Tables:

1. INTRODUCTION

1.1 Background

The secondary objective of the validation trial conducted off Shelburne, N.S. during the fall of 1994 was to collect leeway data on one (1) common SAR target. The purpose of this secondary objective was to assess the impact of conducting simultaneous data collection experiments. This has been previously discussed in the main report. The purpose of this report is to present the preliminary results from the leeway data obtained during the validation trial.

Section 1 of this report provides background information while section 2 provides information about the SAR object and instrumentation. Section 3 discusses the data reduction and analysis process and section 4 provides the results.

The results given in this report are preliminary.

1.2 Leeway Determination

During the field trial leeway speeds and angles were determined directly using an InterOcean S4 current meter. The approach is identical to that used in the Phase II and III leeway experiments conducted off Newfoundland (Fitzgerald et al., 1994). In this direct approach, using the principle of an electromagnetic ship's log, the current meter was tethered to the SAR object to measure velocity relative to the water. Ten minute vector averages based on half second sampling rates were logged. Direction reference was provided by an internal flux-gate compass. Leeway direction was given by the inverse of the logged direction and the difference between the down wind direction and the leeway direction provided leeway angle. The S4 current meter was selected because of its stable hydrodynamic characteristics and its ability to provide accurate current data in the wave zone. The water drag of the current meter and tow frame was at least partially offset by the wind drag on a 0.65 m ARGOS buoy to which the frame was secured. The buoy size was determined from calculations and tests conducted during the Phase II project (Fitzgerald et al., 1993). The centre of the current meter was 0.75 m below the sea surface.

2. SAR OBJECT

The SAR object used for leeway evaluation during the validation trials was a Switlik 6-person life raft. The life raft, shown in Figure B2.1 was deployed with and without drogue. The ballast bags used on this particular life raft during the validation trials are not those normally used on this particular life raft.

2.1 Instrumentation and Equipment

The SAR object was outfitted with the following instrumentation and equipment:

- an R.M. Young anemometer system;
- an air temperature sensor;
- a water temperature sensor;
- a flux-gate compass;
- a data logger;
- an InterOcean S4 current meter;
- a GPS receiver c/w data logger;
- an ARGOS Platform Transmitter Terminal (PTT); and,
- a NOVATECH VHF beacon.

In addition the life raft was fitted with a plywood floor for securing instrumentation and with lifting straps for deploying and recovering the target.

2.2 Data Collection

Positional information on the SAR object was obtained through GPS, ARGOS PTT's and VHF beacons. GPS positions were logged every five minutes while 8 to 10 ARGOS positions were obtained routinely on a daily basis. The VHF beacons provided SAR object direction when the vessel was within VHF range of the SAR object. The GPS data was subsequently used to derive true wind at the SAR object and to obtain total drift displacement.

SAR object headings were determined using a flux-gate compass. Wind direction was computed from a 10 minute unit vector average using a sampling interval of one second. A 10-minute sampling period was selected since it provided statistically stable samples (Dobson, 1981). The standard deviation of wind direction was computed following the algorithm described by Yamartimo (1984). Average wind speed recorded was simply the scalar mean apparent wind speed over the sampling period. 10 minute maximum apparent wind speed was also recorded.

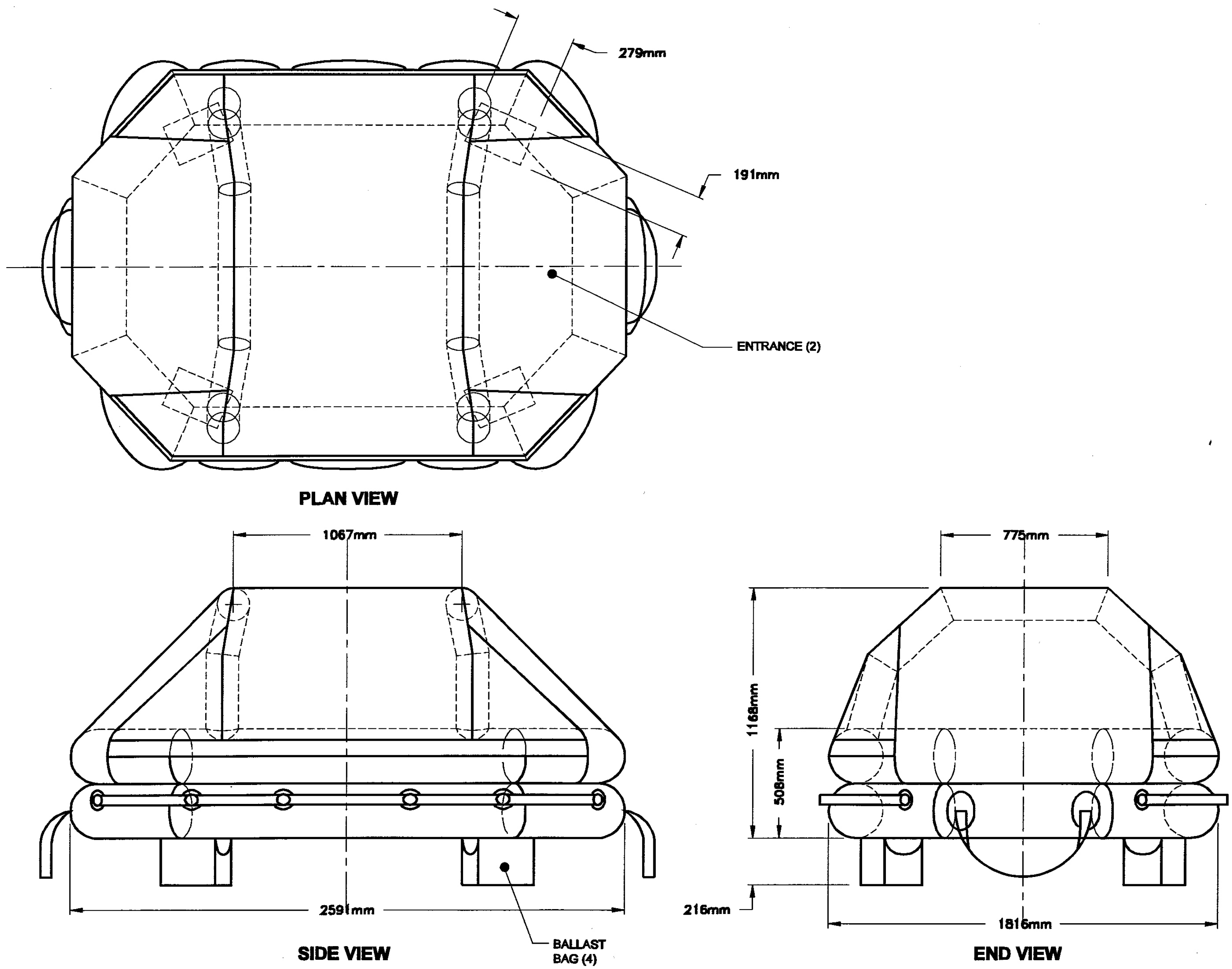

Figure B2.1 - Switlik 6 Person Life Raft

For the 2 drift runs conducted during the validation trials the S4 current meters were programmed to provide 10 minute vector averages of the half-second velocity component samples. Data collection times for the instrumentation package on board the SAR object were synchronized with the S4 data collection program.

Air and sea temperature was recorded every 10 minutes. The air temperature was obtained from an air temperature sensor mounted on the anemometer mast. The height of the air temperature sensor was approximately 1.5 m. The sea temperature was obtained from a water temperature sensor attached just beneath the life raft. These data were used in the adjustment of the true wind to the 10 m reference height.

In total 2 drift runs were conducted, one with a drogue and one without a drogue. For the run conducted without the use of a drogue 51 ten minute records were obtained. For the drift run conducted with a drogue 182 ten minute records were obtained.

3. DATA REDUCTION AND ANALYSIS

3.1 Data Reduction

The data reduction procedure followed that developed during the Leeway Phase III work (Fitzgerald et al., 1994). A brief outline of the reduction procedure follows. The work was carried out in two stages: a preliminary review and examination of the data; followed by further data processing, and the final analysis work. The initial investigation was done using the recorded, apparent wind velocity data in combination with the leeway data derived from the electromagnetic log. The combined data for each drift run were then manually edited to remove data records outside the free drifting period. An initial review and assessment of the data was then done by plotting progressive vector diagrams of leeway and wind velocity, plotting scatterplots, and generating certain descriptive statistics. The primary purpose of this work was to assist in identifying apparent anomalies in the data. Further examination of the data was carried out to assess whether the apparent anomalies were real and, therefore, that the data are valid, or whether the irregularities were a result of instrumentation problems or due to possible changes in SAR object configuration. Configuration changes may occur because of the shipping of water, a tangled drogue, a torn canopy, or, in the extreme, the capsize of the SAR object.

The goal in the second stage was to generate leeway data files in terms of the wind velocity at a reference height of 10 m above the sea surface. The first step was to correct the apparent wind velocities to true wind velocities using the SAR object drift velocity data derived from the smoothed GPS position data. To do this, the recorded five-minute position data were first smoothed using a five point running average. These data were then linearly interpolated to correspond with the ten-minute wind/leeway data times. Finally, the SAR object velocity was computed from the sequence of estimated positions. The true wind velocity and ancillary environmental data were then combined with the leeway velocity data as in the first stage; the leeway parameters of leeway rate, angle, and component velocities were then computed. Manual editing of individual drift run data files was then done to remove spurious records at the beginning and end of each run. In the final step, wind speed data were adjusted from anemometer level to the 10 m reference height using the algorithm described by Smith (1981), and the leeway rate based on the 10 m winds was then calculated. Finally, the data files for the 2 drift runs were imported into SYSTAT, a PC-based statistical software package, for analysis purposes.

3.2 Analysis Methodology

In terms of SAR planning, the ultimate goal of leeway analysis is to derive leeway models which can be used to accurately predict SAR object leeway velocities. Such models, to be operationally useful, need to express leeway in terms of readily available predictors. Model predictors should be physically related to the predictand (SAR object leeway); for instance, wind velocity and, potentially, certain sea state parameters. Ideally, model predictors should be independent of each other. In terms of leeway speed, previous work (Fitzgerald et al., 1994) has shown that, by and large, the relationship between leeway speed and wind speed is highly linear and that typically, the amount of variance explained by wind speed in linear regression models (at zero lag) has been found to be greater than 0.90 ($r^2 > 0.90$), and often greater than 0.95. From this, it is apparent that no other predictors other than an accurate estimate of wind speed, either measured or forecast, is necessary to accurately estimate leeway speed. Cross-correlation analysis has shown (Fitzgerald et al., 1994) that the correlations are highest at zero lag, indicating that the response time is within the sample averaging period of 10 minutes.

Linear regression models of leeway speed (and downwind leeway speed) on wind speed have the form:

$$V_l = a + b * V_{10}; \text{ for } V_{min} <= V_{10} <= V_{max}$$

where: V_l is the leeway speed in knots;
a is the y-intercept;
b is the slope of the regression line;
V_{10} is the wind speed at 10 m above the sea surface in knots;
V_{min} is the minimum 10 m wind speed limit of the development data set in knots; and,
V_{max} is the maximum 10 m wind speed limit of the development data set in knots.

Development of models to estimate leeway angle in terms of readily available predictors has proven to be less tractable. Previous work has suggested that, for certain SAR objects over the range of wind velocities encountered, simple linear models expressing angle off the downwind direction (or crosswind leeway component) in terms of wind speed may explain a significant amount of the variance. It is clear, however, that the general use of such models or extrapolation beyond the range of conditions from which the model was developed cannot be justified. The angle with which the SAR object sails relative to the downwind angle would appear to be highly dependent on the structure of the object (both above and below the waterline) and on the orientation to the wind, sea, and swell. Consequently, developing leeway angles or crosswind leeway models in terms of external forcing mechanisms, without consideration of SAR object design and construction and knowledge of its orientation relative to the external forcing, is likely to prove fruitless.

Therefore, until this can be accomplished, it would seem appropriate to use simple descriptive statistics of leeway angle to estimate the divergence of SAR objects from the downwind direction. This is the approach taken here.

4. PRELIMINARY RESULTS

4.1 Lightly-Loaded 6-person Switlik Life Raft without Drogue

4.1.1 Leeway Speed and Angle

Leeway Speed

The scatterplot of leeway speed against wind speed is shown in Figure B4.1. The regression line of leeway speed on wind speed is also shown. The degree of scatter about the regression line is quite small and is uniform over the entire range of wind speeds encountered. A regression analyses of leeway speed on wind speed was also carried out for this life raft. The results are summarized in Tables B4.1 and B4.2. The amount of variance explained by the linear regression model is 78%. The variation or scatter about the regression line as given by the standard error of the estimate is less than .02 knots.

Table B4.1

Linear Regression of Leeway Speed on 10 m Wind Speed
Switlik 6-person life raft without drogue

No. cases	a	b	r^2	$S_{y\|x}$	Wnd Spd
51	-0.02	0.032	0.782	0.017	5.4-9.9

Table B4.2

Constrained Regression Model - Leeway Speed on 10 m Wind Speed
Switlik 6-person life raft without drogue

No. cases	a	b	r^2	$S_{y\|x}$	Wnd Spd
51	0.000	0.030	0.995	0.017	5.4-9.9

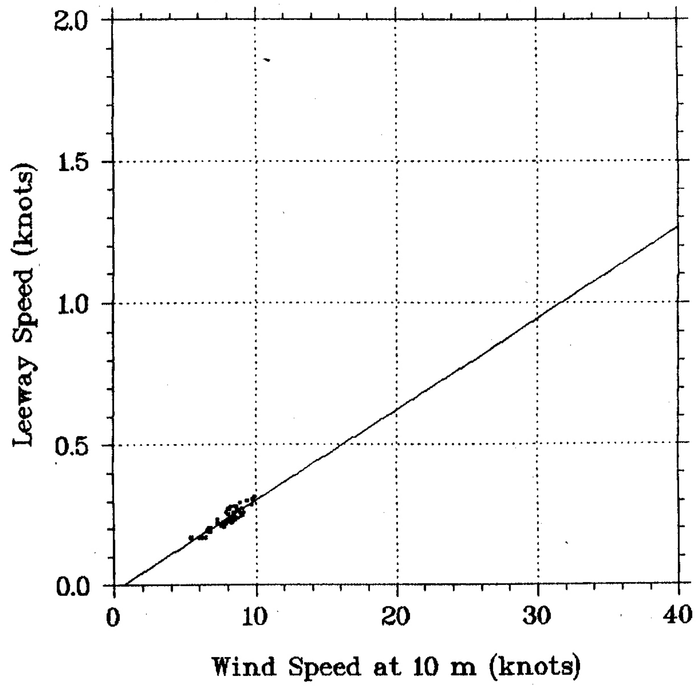

Figure B4.1 Leeway speed against wind speed at 10m, Switlik 6-person life raft without drogue.

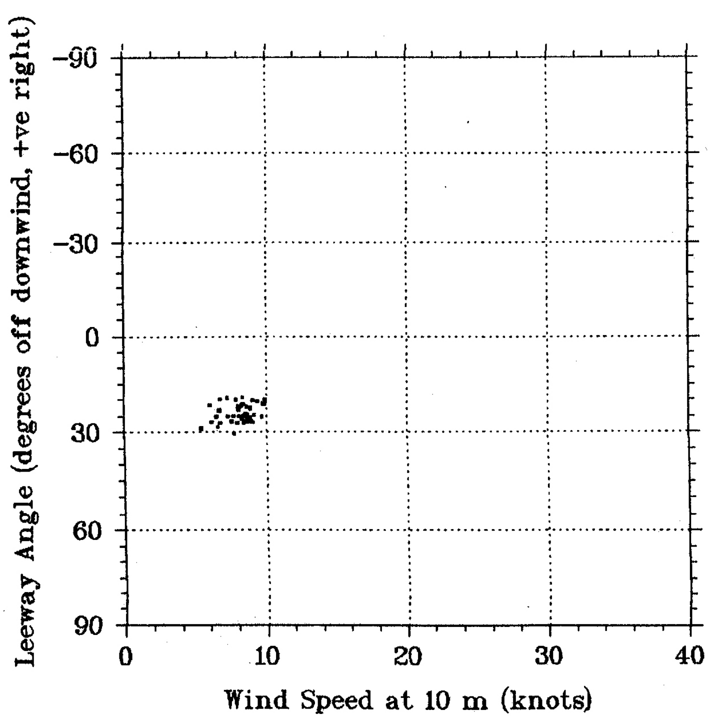

Figure 4B.2 Leeway angle against wind speed at 10m, Switlik 6-person life raft without drogue.

Leeway Angle

The scatterplot of leeway angle versus wind speed is shown in Figure B4.2. The leeway angle statistics are shown in Table B4.3.

Table B4.3

Leeway Angle Statistics
Switlik 6-person life raft without drogue

Wind Speed Range 5.4 - 9.9 knots					
No. Cases	Min.	Max.	Mean	SD	Median
51	19.2	30.4	24.0	2.8	24.9

4.2 Lightly-Loaded 6-person Switlik Life Raft with Drogue

4.2.1 Leeway Speed and Angle

Leeway Speed

The scatterplot of leeway speed against wind speed is shown in Figure B4.3. The regression line of leeway speed on wind speed is also shown. The degree of scatter about the regression line is fairly uniform over the entire range of wind speeds encountered. A regression analyses of leeway speed on wind speed was also carried out for this life raft. The results are summarized in Tables B4.4 and B4.5. The amount of variance explained by the linear regression model is high at 95%. The variation or scatter about the regression line as given by the standard error of the estimate is less than .03 knots.

Table B4.4

Linear Regression of Leeway Speed on 10 m Wind Speed
Switlik 6-person life raft with drogue

No. cases	a	b	r^2	$S_{y\|x}$	Wnd Spd
182	0.035	0.019	0.950	0.029	0.9-26.2

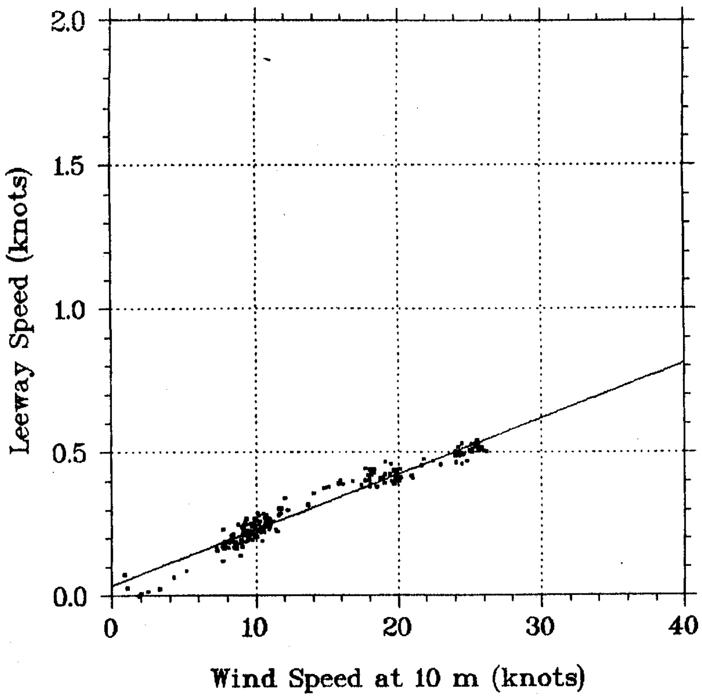

Figure B4.3 Leeway speed against wind speed at 10m, Switlik 6-person life raft with drogue.

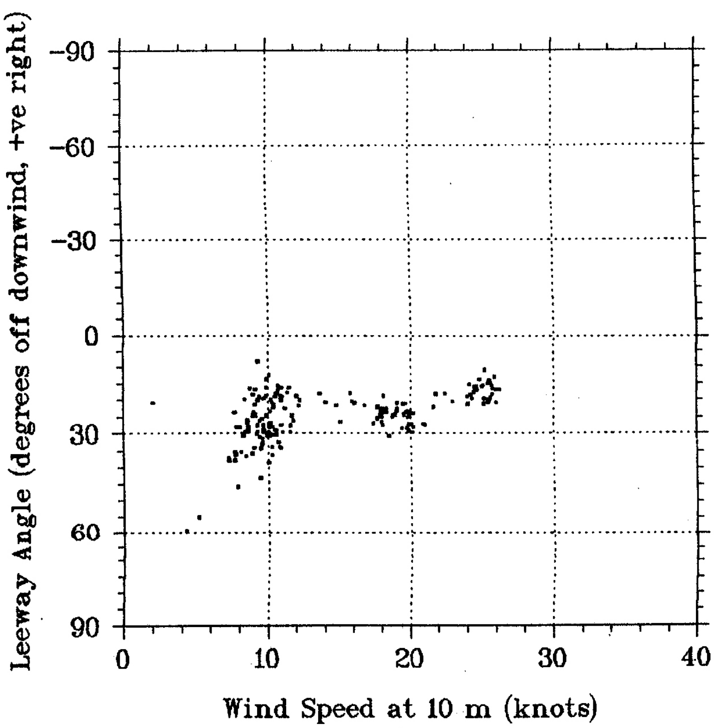

Figure B4.4 Leeway angle against wind speed at 10m, Switlik 6-person life raft with drogue.

Table B4.5

Constrained Regression Model - Leeway Speed on 10 m Wind Speed
Switlik 6-person life raft with drogue

No. cases	a	b	r^2	$S_{y\|x}$	Wnd Spd
182	0.000	0.021	0.991	0.033	0.9-26.2

Leeway Angle

The scatterplot of leeway angle versus wind speed is shown in Figure B4.4. The leeway angle statistics are shown in Table B4.6 and B4.7. Table B4.6 shows the leeway angle statistics in wind speeds over the entire range of wind speeds while Table B4.7 shows the leeway angle statistics in wind speeds of 10 knots or greater.

Table B4.6

Leeway Angle Statistics
Switlik 6-person life raft without drogue

Wind Speed Range 0.9 - 26.2 knots					
No. Cases	Min.	Max.	Mean	SD	Median
182	-170.6	139.9	22.8	25.7	23.8

Table B4.7

Leeway Angle Statistics
Switlik 6-person life raft without drogue

Wind Speed 10 knots or greater					
No. Cases	Min.	Max.	Mean	SD	Median
122	10.9	38.7	22.7	5.4	21.8

4.3 Summary

The results given here are to be considered preliminary. However, the results are similar to results obtained for other life rafts tested during previous leeway trials (Fitzgerald et al., 1994).

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