TP 13290E

TARGET DETECTION EXPERIMENT
PHASE III – DATA ANALYSIS

by

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16. Abstract

This report covers the final phase of a three-phase project. The project objectives were:

- to develop methodologies for conducting probability of detection (POD) field trials using free-drifting common search and rescue (SAR) targets;
- to conduct experimental searches using visual and electronic sensors from various search platforms for common SAR targets; and
- to use the collected data to establish POD models for the various platform/sensor/target combinations and for input into related SAR research.

The objectives of Phase III were:

- to conduct an inventory of all available marine SAR POD data sets, Canadian and U.S.;
- to merge the data sets into a unified data base;
- to provide a POD calculation and analysis tool as part of the data base; and
- to conduct a data analysis using the newly constructed data base.

SAR detection data dating back to 1986 was assembled and transferred into a newly defined unified data base. An SAR data analysis software (SARDAS) package was developed as part of the data base. This software package was used to generate POD models from the unified data base. This report provides model coefficients for most of the POD data sets that were assembled under this project. Sweep width curves are presented for selected data sets.

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16. Résumé

Ce rapport traite de la troisième et dernière phase d'un projet à long terme dont les objectifs étaient les suivants :

- mettre au point des méthodes d'essai en mer utilisant des cibles courantes d'opérations de recherche-sauvetage, pour l'étude de la probabilité de détection (PD);
- mener des recherches expérimentales d'objets flottants, à l'aide de moyens de détection visuels et électroniques, depuis diverses plates-formes de recherche;
- utiliser les données recueillies pour établir des modèles de PD pour diverses combinaisons plate-forme/moyen de détection/cible, et pour des études connexes dans le domaine de la recherche-sauvetage.

Quant aux objectifs de la phase III, ils s'énonçaient comme suit :

- recenser les ensembles de données de PD compilés au Canada et aux États-Unis relativement aux opérations maritimes de recherche-sauvetage;
- fusionner ces données en une seule et même base de données;
- élaborer un outil de calcul et d'analyse des PD et l'intégrer à la base de données;
- appliquer cet outil à l'analyse des données comprises dans la nouvelle base de données.

Les données de détection de cibles flottantes remontant à 1986 ont été rassemblées et transférées dans une nouvelle base de données unifiée. Un progiciel d'analyse des données de recherche-sauvetage (SARDAS, pour *SAR data analysis software*) a été développé et intégré à cette base de données. Ce logiciel a permis de générer des modèles de PD à partir de cette vaste base de données. Le présent rapport donne les coefficients des modèles tirés de la plupart des ensembles de données de PD édifiés dans le cadre du présent projet. Il présente aussi, pour certains ensembles de données, des courbes de probabilité de détection dont sont déduites des largeurs de balayage moyennes.

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EXECUTIVE SUMMARY

This report represents the final phase of a three-phase project. The overall project objective was to develop methodologies for conducting Probability of Detection (POD) field trials using free-drifting objects, to conduct visual and electronic detection trials using common Search and Rescue (SAR) targets, and to use the collected data to model the various platform/sensor/target combinations.

Phase I Objective

The objective of Phase I was to develop an experiment plan that would be used in future detection experiments conducted during the various phases of this project.

Phase II Objective

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

Phase III Objective

The objective of Phase III was 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 modeling.

Background

This multi-phase project was 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 POD curves for certain platform/sensor/target combinations.

A pilot detection experiment was conducted during the fall of 1994 off Shelburne, Nova Scotia, in which free drifting 4- and 6-person life rafts were used as SAR targets. Leeway data was also collected during this pilot experiment as well as SAR target track information which has been used for input into the CANSARP (Canadian Search and Rescue Planning Program) validation project.

In 1995 a full-scale detection experiment was conducted on the Grand Banks of Newfoundland and in Conception Bay, Newfoundland. The search vessels were the M.V. Nain Banker and the CCGS “Sir Humphrey Gilbert. Visual and night vision goggle (NVG) searches were conducted from the

M.V. Nain Banker while radar searches were conducted from the CCGS Sir Humphrey Gilbert. The targets of interest were small boats, life rafts and persons in the water (PIWs). Above normal conditions were experienced offshore throughout the field trials. The sea conditions seriously affected search activity and deployment/recovery operations.

The following outlines many of the findings and conclusions of the 1995 trials:

- A total of 27 searches were conducted during the 1995 field trials for life rafts, small boats, and PIWs. Searches were conducted from the MV Nain Banker and the CCGS Sir Humphrey Gilbert. The sensors included binoculars during day time, NVGs, and radar.

- POD data was collected for 12 platform/target/sensor combinations (search types).

- Leeway data was collected on three (3) SAR targets in the normal and swamped condition yielding six (6) leeway configurations.

- Track data was obtained for seven (7) life rafts and two (2) boats in both the normal and swamped condition for input into the CANSARP validation project. As well, track data was collected for numerous PIW tracks in Conception Bay.

- The MV Nain Banker is similar in size to a 900 Class CCG vessel. The height of eye on the MV Nain Banker is 7.5 m at the bridge level. This height of eye is very close to the height of eye of the CCGC Bickerton at the Monkey Island level.

- Searches on board the MV Nain Banker were conducted from inside the bridge, looking through the bridge windows.

- When seas reached 3-4 m the view through the bridge windows of the MV Nain Banker became obscured by sea spray.

- Lookouts on board the MV Nain Banker found the Litton Model M-972 NVGs to be more suitable for searching than the Night Mariner NVGs.

- The use of drifting SAR targets for detection experiments resulted in data collection to support related SAR research. However, trying to collect leeway data on five (5) targets may have been too ambitious for the time of year.

- For the data set collected, the Sperry 4016 radar provided promising results against small boats outfitted with radar reflectors.

- For the data set collected, the TITAN system provided promising results against life rafts with simulated persons on board and PIWs. The TITAN system was not tested against small boats.

- For the data set collected, there were no NVG detections for PIWs outfitted with retro-reflective tape.

- For the data set collected, the detection rate for PIWs during daylight visual searches was approximately 40% for opportunities in the 0-1 nmi lateral range bin.

The following were the data analysis recommendations arising from the 1995 trials:

- Perform POD analysis on the following data sets for the purposes of getting a preliminary measure of sweep width:

    - daylight visual for PIWs;
    - 4016 Radar for PIWs;
    - 4016 Radar for boats and life rafts;
    - TITAN display system for PIWs; and,
    - MRI/AI Tracker for life rafts and PIWs.

- Perform leeway analysis on the leeway data collected during the 1995 experiment.

- Use SAR target tracks obtained during the 1995 trials for input into CANSARP validation.

- Incorporate the issue of false detections into future target detection analysis.

Objectives of Phase III

The following were the main objectives specific to this Phase III project.

- Conduct on an inventory of all available marine SAR POD data sets, Canadian and US.

- Merge the data sets into one data base.

- Provide a POD calculation and analysis tool as part of the data base.

- Conduct a data analysis using the newly constructed data base.

All of these objectives were met during the project. The following are the findings and recommendations arising from this project.

Phase III Findings and Recommendations

Findings

Data Management and Software Development

Much of the experimental search data collected by the CCG and USCG dating back to 1986 has been assembled under this project. The USCG data primarily consisted of processed data ready for input into POD modeling. In addition to POD modeling input data, many ancillary data sets were assembled with respect to the CCG data.

Data base formats were designed for both field data collection and for model input data. The data base was designed following a review of formats used in past experiments.

All assembled data was transferred to Excel format and entered into the newly designed, unified data base formats.

A major part of the project was the development of a data management and analysis software tool. This tool came to be known as the SAR Data Analysis Software (SARDAS).

SARDAS was used to review all the POD data sets assembled and provide POD models for each of the data sets reviewed. For the most part model results were very similar to those results that were published from previous experiments.

Daylight Visual Searches

Based on the data assembled, daylight visual average sweep widths ranged from 3.4 nmi (CCGS Jackman) to 5.4 nmi (USCGC Vigorous). Vessel stability and height of eye have an obvious influence on detection performance.

There has been only one data set collected on daylight visual searching for PIWs with orange survival suits. This was carried out by the M.V. Nain Banker during the 1995 trials. Results showed a sweep width of 0.8 nmi based on average conditions. The data set should be considered preliminary.

Sweep width for daylight visual searches for hand-held orange smoke flares ranged from 3.4 nmi for USCG Utility Boats (UTBs) to 5.6 nmi for USCG Work Patrol Boats (WPBs). Data was collected in very light conditions with an average wind speed of 5 kn and an average wave height of 0.5 m.

Night Visual Searches

Only a small data set was found for night visual searches against life raft canopy lights. This was for the CCGS Alert. There were only 18 records and the sweep width result was 0.7 nmi. There were other night visual searches for lights conducted by the CCGS Sir William Alexander; however, this data could not be found.

Night visual searches for white strobe lights from UTBs and WPBs combined, yielded a sweep width of 2.0 nmi. The data set consisted of 336 detection opportunities. The data was collected in light conditions with average wind speeds of 9 kn and average wave heights of 0.8 m.

Night visual searches for hand-held red flares by UTBs and WPBs yielded sweep widths of 10.4 nmi and 12.7 nmi respectively. Each data set contained in excess of 200 detection opportunities, however, the data was collected in very light conditions with average wind speeds of 6 kn and average wave heights of 0.5 m.

Night Vision Goggle (NVG) Searches

There were two data sets for NVG searches against PIWs with reflective tape. One data set was collected by USCG UTBs and consisted of 239 detection opportunities. This data set was collected in wind speeds under 10 kn and yielded an average sweep width of .07 nmi. A small data set was collected by the M.V. Nain Banker which consisted of 24 detection opportunities of which none were detected.

NVG searches conducted by USCG UTBs for small boats ranging from 5.5 m to 6.4 m yielded an average sweep width of 0.2 nmi.

NVG searches were conducted from USCG UTBs for 4- and 6-person life rafts without reflective tape. With no moon visible average sweep widths were in the order of 0.2 nmi. In moonlit conditions average sweep width for this type of target increased to 0.6 nmi.

NVG searches for 4- and 6-person life rafts with reflective produced average sweep widths ranging from 0.2 nmi to 1.0 nmi. These searches were conducted from USCG UTBs, the CCGS Alert, and the USCGC Vigorous. A small data set, consisting of 16 detection opportunities, was also collected from the M.V. Nain Banker; however, there were no detections.

NVG searches for 4- and 6-person life raft canopy lights produced sweep widths of 4.6 nmi for the CCGS Alert and 6.2 nmi for the USCGC Vigorous. Wind conditions were in the 15-20 kn range with waves averaging 1.8 m.

Generally NVGs had better performance in moonlit conditions and NVGs performed far better against illuminated targets as opposed to reflective tape.

Surface Radar Searches

The Sperry 127E radar was tested on the CCGS Jackman against 4-person life rafts with and without radar reflectors. Although detection opportunities were small the performance of the radar against targets with reflectors was three times better than the performance against life raft targets without reflectors as measured by sweep width.

The performance of the Sperry 4016 radar against small wooden boats with hi-flyer radar reflectors was in the order of 4.8 m for the conditions encountered.

The performance of the TITAN against PIW targets as measured by sweep width was 1.2 nmi for the conditions encountered versus 0.2 nmi for the Sperry 4016 for the same target. Although data sets were relatively small this is a positive indication that the detection of small targets can be greatly improved though enhancement and processing of the raw radar data.

Recommendations

Data Base and Software Related

1. **Do a re-analysis of the Canadian POD ancillary data assembled during this project for the purpose of deriving further data that would be input into the present POD data base.**

This would make the present POD data base more complete and would bring Canadian POD data more in line with the American POD data that has also been assembled during this project. The result could increase the number of variables to be analyzed for platform/target/sensor data sub-sets that contain both Canadian and American POD data and also allow for a more thorough analysis of the Canadian data.

2. **Continue with the development of the SARDAS data base in terms of creating a unified leeway data base and software tools for the analysis of such data.**

This project has assembled the leeway data collected by the CCG and the USCG since 1992. This data needs to be put into a unified data base similar to the POD data. Data collected prior to 1992 be reviewed and where practical included with the leeway unified data base. Any software tools developed for leeway analysis could also include tools for extracting sub-sets from the data base that could be used for input into the CANSARP evaluation project.

3. **The Coast Guard should investigate the establishment of a sweep width data base and sweep width Calculator for inclusion in the CANSARP program.**

This recommendation was put forth as part of the final report on the Joint SAR Trails conducted by the CCG and USCG conducted in 1990 on the Canso Bank off Nova Scotia. The report was TP 11654E, March 1993. It recommended at that time that a data base should be established from the results from the various CCG and USCG SAR detection experiments carried out to date. Included in this data base should be information on search vessels, type of search, type of target, significant parameters affecting searches, regression coefficients of significant parameters, and finally the ability to easily calculate sweep width given the values of significant parameters.

This recommendation is another logical follow-on to this project on developing a unified data base together with tools for conducting POD analyses and calculation of sweep width..

4. A project should be undertaken to catalogue and assemble the many reports that exist today on POD and Leeway experiments conducted by the CCG and USCG.

The above would be of obvious value to researchers both in and outside the Coast Guard. All reports could be assembled on CD and where practical could include reference material contained in these reports.

5. The Coast Guard should consider initiating a program to establish and maintain a data base of the types of life rafts and/or lifeboats carried by vessels operating in Canadian waters.

These data would help search planners better estimate leeway and total drift and, also, provide a necessary input required to specify search sweep width. This work could start as a regional pilot project to obtain an estimate of the scale of a full cataloguing effort and the work required to maintain the data base.

<u>POD Experiment Related</u>

6. Undertake a pilot project to utilize the Marine Simulator in St. John's for conducting SAR target detection experiments.

If this were practical it would allow POD data to be collected at an accelerated rate. The main opposition to this approach appears to be the question "How close can actual conditions be simulated?" Some have suggested that results from a simulated search would not be meaningful. The following paragraphs outline a solution that could render search results from a marine simulator to be of significant value.

The basic approach would be to compare the results obtained from a simulated search with known conditions from a completed SAR detection experiment. There exists today complete search experiment data sets that contain all the parameters to re-create a search scenario. The data set of the 1990 experiment conducted on the Canso Bank involved both CCG and USCG search vessels. The availability of such data leads to a solution of the validation problem, independent of simulator fidelity. From the trial data all search parameters can be programmed into the marine simulator. These would include such parameters as search tracks, vessel speed, sea conditions, target location, target type, and so forth. The subsequent sweep width results from a simulator search could then be calibrated against sweep results obtained from the field trails.

7. Continue collecting radar search data using standard marine radar for small targets that are equipped with and without radar reflectors.

Several small data sets were collected in 1995 as well as in previous experiments dating back to 1986. This work needs to continue so that a sound sweep baseline can be established for the standard marine radar against common small SAR targets. Even with the advent of new technology such as the MRI and AI Tracker most vessels today still carry marine radars that use standard processing methods.

8. Continue collecting POD data for new technologies such as the MRI and AI Tracker and develop POD models for these technologies against common small SAR targets.

The above types of new technologies have shown themselves to outperform a standard marine radar. However, this performance needs to be well documented in a realistic comparison trial by an independent party. If these new technologies significantly out-perform standard radars, more support could be had for further R&D, not only from within the government but also within the private sector, e.g., the oil industry.

9. Increase the effort to develop POD models for NVGs against common small targets.

NVGs have now become more common on CCG vessels.

10. Continue to review and address data collection recommendations put forth in Phases I and II of this three-phase project, concentrating on those types of vessels from which detection data has already been collected.

By filling out the data collection data sets of selected vessel types this would establish sweep boundaries for other platform/target/sensor combinations.

Leeway Experiment Related

11. Conduct a project that would see leeway models developed for certain common SAR targets followed by a field trail to validate these models.

The leeway dynamics project has used the 1992 and 1993 leeway data sets as data sets for the development of models for a 4-person life raft and 5.6 m boat. The next logical step is to develop models for common SAR targets for which no data exists. These models should then be validated independently in a field trial. If the models perform well this would lead to an acceleration in the development of leeway models for many common SAR targets and most importantly the search planner can use these models with confidence.

Such a field trial could also be tied into the collection of data for related SAR research.

12. Re-examine the 1992 and 1993 leeway data to determine the influence of waves on the motion of a drifting SAR target.

During the 1992 and 1993, leeway experiments a certain amount of wave data was collected in support of these trials. However, waves were not investigated specifically to determine their influence on total drift. It may also be worthwhile to re-examine other issues such as cross wind component or leeway angle over a longer averaging period.

SOMMAIRE

Ce rapport rend compte de la troisième et dernière phase d'un projet qui poursuivait les objectifs suivants :

- mettre au point des méthodes d'essai en mer utilisant des objets flottants pour l'étude de la probabilité de détection (PD) de ces cibles;
- mener des essais de détection d'objets flottants, à l'aide de moyens de détection visuels et électroniques;
- utiliser les données recueillies pour établir des modèles de PD correspondant aux diverses combinaisons plate-forme/moyen de détection/cible.

Objectif de la phase I

Cette phase avait pour objet la mise au point de la démarche expérimentale pour les essais de détection à mener lors des diverses phases du projet.

Objectif de la phase II

Cette phase, entreprise à l'automne 1995, comportait des recherches expérimentales en mer qui mettaient en jeu divers moyens de détection et au terme desquels ont été recueillies les données nécessaires, selon la démarche expérimentale définie à la phase I.

Objectif de la phase III

L'objectif de la phase III était d'utiliser les données recueillies au cours de la phase II pour modéliser les combinaisons plate-forme/moyen de détection/cible mises à l'essai, accroître la précision des modèles de dérive des cibles, évaluer l'efficacité des circuits de recherche, et perfectionner l'état de la technique de modélisation des opérations de recherche-sauvetage.

Historique

Ce projet de longue haleine s'inscrit dans la suite de projets semblables menés en 1986 dans la baie de Placentia, à Terre-Neuve, puis en 1987, 1988 et 1990 au large du Banc de Canso, en Nouvelle-Écosse. Ces expériences, menées pour le compte de la Garde côtière canadienne (GCC) et du Centre de développement des transports, étaient appuyées par la garde côtière des États-Unis. Les cibles utilisées pour ces expériences étaient captives : les chercheurs décrivaient divers circuits de recherche afin de colliger les données nécessaires à l'établissement des courbes de PD pour certaines combinaisons plate-forme/moyen de détection/cible.

Une expérience-pilote de détection de cibles dérivantes (non captives), soit des radeaux de sauvetage à 4 et 6 places, a été réalisée à l'automne 1994 au large de Shelburne, en Nouvelle-Écosse. Au cours

de cette expérience, en plus des données sur la trajectoire des cibles, ont été colligées les données de dérive due au vent, aux fins de la validation du logiciel CANSARP (Programme canadien de planification de recherche et sauvetage).

En 1995, était lancée une expérience à grande échelle de détection d'objets flottants, au large des Grands Bancs de Terre-Neuve et dans la baie de la Conception, à Terre-Neuve. Les plates-formes de recherche utilisées étaient le NM *Nain Banker* et le navire *Sir Humphrey Gilbert* de la GCC. Les moyens de détection mis en oeuvre à bord du NM *Nain Banker* étaient la recherche à vue et les lunettes de vision nocturne (LVN), tandis qu'un radar était utilisé à bord du *Sir Humphrey Gilbert.* Les cibles étaient des petites embarcations, des radeaux de sauvetage et des mannequins représentant des personnes à la mer. Tous les essais en mer ont été réalisés dans des conditions relativement rigoureuses. Ainsi, la hauteur des vagues rendait difficiles la recherche et les opérations de déploiement/récupération.

Voici un résumé des essais de détection menés en 1995 et des résultats et conclusions qui ont découlé de ces travaux :

- Au total, 27 recherches ont été menées. Les cibles étaient des radeaux de sauvetage, des petites embarcations et des personnes à la mer; les plates-formes de recherche, le NM *Nain Banker* et le navire *Sir Humphrey Gilbert* de la GCC; et les moyens de détection, des jumelles pendant le jour, des lunettes de vision nocturne et des radars.
- Des données de PD ont été recueillies pour 12 combinaisons plate-forme/cible/moyen de détection (ou types de recherche).
- Les données de dérive due au vent ont été recueillies pour trois (3) cibles, lorsqu'elles flottaient normalement et lorsqu'elles étaient remplies d'eau : on a ainsi obtenu six (6) configurations de dérive due au vent.
- Les données sur la trajectoire des cibles ont été colligées pour sept (7) radeaux de sauvetage et deux (2) embarcations, flottant normalement et remplies d'eau, aux fins de la validation du CANSARP. Des données ont également été recueillies sur la trajectoire de plusieurs «personnes à la mer», dans la baie de la Conception.
- De par ses dimensions, le navire NM *Nain Banker* peut être assimilé à un navire de classe 900 de la GCC. La hauteur de l'oeil à bord du NM *Nain Banker* est de 7,5 m au niveau de la passerelle, soit sensiblement la même qu'à bord du navire *Bickerton* de la GCC, toujours au niveau de la passerelle de navigation.
- Les recherches à bord du NM *Nain Banker* ont été menées depuis l'intérieur de la passerelle, à travers les fenêtres.
- Lorsque les vagues atteignaient 3 à 4 m de hauteur, les embruns entravaient la vision par les fenêtres de la passerelle du NM *Nain Banker.*
- Selon les vigies à bord du NM *Nain Banker*, les lunettes de vision nocturne Litton, modèle M-972, offrent de meilleures performances, pour la recherche, que les LVN de marque Night Mariner.
- L'utilisation de cibles dérivantes (plutôt que captives) a permis la collecte de données utiles à des études connexes sur la recherche-sauvetage. Mais il aurait été trop ambitieux, compte tenu de l'époque de l'année où ont eu lieu les essais, de vouloir colliger les données de dérive due au vent pour cinq (5) cibles.

- D’après l’ensemble de données recueillies, le radar Sperry 4016 a donné des résultats prometteurs pour la détection de petites embarcations munies de réflecteurs radar.
- D’après l’ensemble de données recueillies, le système TITAN a donné des résultats prometteurs pour la détection de radeaux de sauvetage avec mannequins embarqués et de personnes à la mer. Ce système n’a pas été mis à l’essai pour la recherche de petites embarcations.
- D’après l’ensemble de données recueillies, les LVN n’ont permis aucune détection de personne à la mer portant des bandes rétroréfléchissantes.
- D’après l’ensemble de données recueillies, le taux de détection de personnes à la mer au cours de recherches visuelles diurnes est d’environ 40 p. cent, pour des cibles situées dans une plage de distances latérales de 0 à 1 mille marin (M).

Voici les recommandations formulées pour l’analyse des données issues des essais de 1995 :

- Effectuer des analyses de la PD sur les ensembles de données suivants, afin d’obtenir une estimation préliminaire de la largeur de balayage :
    - recherche visuelle diurne de personnes à la mer;
    - recherche de personnes à la mer au moyen d’un radar 4016;
    - recherche d’embarcations et de radeaux de sauvetage au moyen d’un radar 4016;
    - recherche de personnes à la mer au moyen du système TITAN;
    - recherche de radeaux de sauvetage et de personnes à la mer au moyen du pisteur IA/IMR.
- Analyser les données de dérive due au vent issues des expérimentations de 1995.
- Utiliser les trajectoires d’objets flottants observées lors des expérimentations de 1995 pour la validation du CANSARP.
- Prendre en compte les fausses détections lors des analyses futures des données de détection.

Objectifs de la phase III

Voici les principaux objectifs associés à la phase III :

- Recenser les ensembles de données de probabilité de détection d’objets flottants, compilés au Canada et aux États-Unis.
- Fusionner les ensembles de données en une seule et même base de données.
- Élaborer un outil de calcul et d’analyse de la PD et l’intégrer à la base de données.
- Appliquer cet outil à l’analyse de la nouvelle base de données unifiée.

Tous ces objectifs ont été atteints.

Conclusions et recommandations de la phase III

Conclusions

Gestion des données et développement d’outils logiciels

Le présent projet a permis de rassembler la plupart des données issues des expérimentations effectuées par la GCC et la USCG depuis 1986. Les données de la USGC étaient principalement constituées de données déjà traitées pouvant contribuer telles quelles à la modélisation de la PD. Dans le cas de la GCC, outre les données utiles pour la modélisation de la PD, de nombreux ensembles de données accessoires ont été réunis.

Des schémas d’organisation des bases de données ont été mis au point pour la collecte de données d’essai ainsi que pour les données de modélisation. Les structures élaborées respectent les schémas utilisés au cours des expériences antérieures.

Toutes les données retenues ont été converties au format Excel et introduites dans la nouvelle base de données unifiée.

Une part importante des travaux a consisté à développer un logiciel de gestion et d’analyse de données. Cet outil a été baptisé SARDAS, pour *SAR Data Analysis Software*.

Le SARDAS a été appliqué à tous les ensembles de données de PD rassemblés et a généré des modèles de PD pour chacun des ensembles de données analysés. La plupart du temps, les modèles obtenus reflétaient fidèlement les résultats publiés à l’issue d’expérimentations antérieures.

Recherches visuelles diurnes

Les largeurs de balayage établies pour les recherches visuelles diurnes allaient de 3,4 M (navire *Jackman* de la GCC) à 5,4 M (garde-côte *Vigorous* de la USCG). La stabilité du navire et la hauteur de l’oeil influent, évidemment, sur le taux de détection.

Un seul ensemble de données a été colligé pour des recherches visuelles diurnes de personnes à la mer portant une combinaison de survie de couleur orange. Ce type de recherche a eu lieu en 1995, à bord du NM *Nain Banker*. La largeur de balayage obtenue était de 0,8 M, dans des conditions moyennes. Mais aucune conclusion ne peut être tirée de cet ensemble de données.

Dans le cas de recherches visuelles diurnes d’engins fumigènes à main de couleur orange, la largeur de balayage obtenue variait de 3,4 M, pour les bateaux de service (UTB, pour *utility boats*) de la USCG, à 5,6 M, pour les bateaux patrouilleurs (WPB, *work patrol boats*), toujours de la USCG. Ces essais ont eu lieu dans des conditions très favorables (vitesse moyenne du vent de 5 noeuds et vagues d’une hauteur moyenne de 0,5 m).

Recherches visuelles nocturnes

On ne dispose que d'un ensemble restreint de données sur des recherches visuelles nocturnes de radeaux de sauvetage fermés surmontés de feux. Ces recherches ont eu lieu à bord du navire *Alert* de la GCC. L'ensemble ne comportait que 18 occasions de détection, pour une largeur de balayage résultante de 0,7 M. D'autres recherches visuelles de nuit portant sur des feux ont été effectuées à bord du *Sir William Alexander* de la GCC, mais les données afférentes sont demeurées introuvables.

Les données sur des recherches visuelles de nuit portant sur des feux à éclats blancs, effectuées depuis des UTB et ou des WPB, ont généré une largeur de balayage de 2,0 M. Les fichiers de données combinés des deux types de navires comportaient 336 occasions de détection. Les données ont été colligées dans des conditions clémentes, soit des vents moyens de 9 noeuds et des vagues d'une hauteur moyenne de 0,8 m.

Les recherches visuelles de feux à main de couleur rouge effectuées la nuit par des UTB et des WTB ont donné une largeur de balayage de 10,4 M et de 12,7 M respectivement. Chaque ensemble de données contenait plus de 200 occasions de détection; il faut toutefois préciser que les données ont été colligées dans des conditions très clémentes, soit par des vents de 6 noeuds et dans des vagues de 0,5 m de hauteur, en moyenne.

Recherches au moyen de lunettes de vision nocturne (LVN)

Deux ensembles de données ont été constitués à partir de recherches LVN de cibles représentant des personnes à la mer portant du ruban réfléchissant. Un de ces ensembles, colligé par un bateau de service de la garde côtière américaine, comportait 239 occasions de détection. Constitué alors que les vents soufflaient à moins de 10 noeuds, il a donné une largeur de balayage de 0,07 M. Un petit ensemble de données constitué par le NM *Nain Banker* comportait 24 occasions de détection : aucune détection n'a été effectuée.

Les recherches LVN menées depuis les UTB de la USCG et portant sur des petites embarcations de 5,5 m à 6,4 m ont donné une largeur de balayage de 0,2 M.

Des recherches LVN ont été menées depuis des UTB sur des radeaux de sauvetage à 4 et 6 places, non munis de ruban réfléchissant. Par des nuits sans lune, les largeurs de balayage moyennes étaient de l'ordre de 0,2 M. Sous l'éclairage de la lune, la largeur de balayage moyenne pour ce type de cible était portée à 0,6 M.

Les recherches LVN de radeaux de sauvetage à 4 et 6 places munis de ruban réfléchissant ont mené à des largeurs de balayage allant de 0,2 M à 1,0 M. Ces recherches ont eu lieu à bord d'UTB de la USCG, du navire *Alert* de la GCC et du garde-côte *Vigorous* de la USCG. Un ensemble de données restreint, constitué de 16 occasions de détection, a également été colligé à bord du NM *Nain Banker*; mais aucune cible n'a été détectée.

Les recherches LVN de radeaux de sauvetage à 4 et 6 places fermés surmontés de feux ont produit des largeurs de balayage de 4,6 M pour le navire *Alert* de la GCC et de 6,2 M pour le garde-côte *Vigorous* de la garde côtière des États-Unis. Les vents atteignaient en moyenne 15 à 20 noeuds et les vagues, 1,8 m.

Règle générale, les LVN étaient plus performantes lorsque la lune éclairait, et elles étaient beaucoup plus efficaces pour la détection de cibles lumineuses que de cibles munies de ruban réfléchissant.

Recherches par radar de surface

Le radar Sperry 127E a été essayé à bord du navire *Jackman* de la GCC, pour la recherche de radeaux de sauvetage à 4 places, avec et sans réflecteurs radar. Malgré le petit nombre d'occasions de détection étudiées, le radar s'est révélé trois fois plus performant, selon le critère «largeur de balayage», lorsque les cibles étaient munies de réflecteurs radar que lorsqu'elles n'en étaient pas munies. La performance du Sperry 4016 dans la détection de petites embarcations de bois munies de réflecteurs radar en hauteur était de l'ordre de 4,8 M, dans les conditions d'essai.

La performance du système TITAN pour la détection de cibles représentant des personnes à la mer, exprimée en largeur de balayage, était de 1,2 M pour les conditions d'essai, tandis que celle du Sperry 4016 était de 0,2 M, pour la recherche des mêmes cibles. Malgré le caractère relativement restreint des ensembles de données, on peut penser que la collecte et le traitement de meilleures données radar brutes peuvent favoriser la détection des cibles de petites dimensions.

Recommandations

Base de données et outils logiciels

1. **Soumettre à une nouvelle analyse les «données accessoires» de la GCC rassemblées dans le cadre du présent projet, afin d'en tirer d'autres données susceptibles d'enrichir la base de données de PD existante.**

À la suite d'une telle analyse, la base de données de PD existante serait plus complète et les données canadiennes, plus conformes aux données américaines réunies dans le cadre du projet. Il pourrait en résulter un plus grand nombre de variables à analyser pour les sous-ensembles de données plate-forme/cible/moyen de détection contenant à la fois des données canadiennes et américaines, et la possibilité d'une analyse plus exhaustive des données canadiennes.

2. **Poursuivre le développement de la base de données SARDAS, en créant une base unifiée de données de dérive due au vent et des outils logiciels pour l'analyse de ces données.**

Le présent projet a été l'occasion de rassembler les données de dérive due au vent colligées par la GCC et la garde côtière des États-Unis depuis 1992. Ces données doivent être réunies à l'intérieur d'une base de données unifiée, comme l'ont été les données de PD. Il y aurait lieu aussi d'examiner les données colligées avant 1992 et de les intégrer, dans la mesure du possible, à la base de données de dérive unifiée. Tout nouveau logiciel d'analyse de la dérive due au vent pourrait aussi comporter des outils permettant d'extraire de la base de données des sous-ensembles à intégrer au projet d'évaluation du logiciel CANSARP.

3. Envisager l'établissement, par la Garde côtière canadienne, d'une base de données des largeurs de balayage et d'un outil de calcul des largeurs de balayage pour intégration au CANSARP.

Cette recommandation figurait dans le rapport final (CDT, mars 1993, TP 11654E) des expérimentations conjointes menées par la GCC et la USCG en 1990 au large du Banc de Canso, en Nouvelle-Écosse. Les chercheurs avaient alors recommandé l'établissement d'une base de données à partir des résultats des divers essais de détection d'objets flottants menés jusqu'alors par la GCC et la USCG. Une telle base devrait englober des données sur les navires de recherche, le type de recherche, le type de cible, les variables significatives influant sur la recherche, les coefficients de régression des variables significatives, et une fonction de calcul rapide de la largeur de balayage à partir des valeurs attribuées aux variables significatives.

Cette recommandation s'inscrit dans la suite logique du présent projet, qui vise le développement d'une base de données unifiée de même que d'outils pour l'analyse de la PD et le calcul de la largeur de balayage.

4. Lancer un projet visant à cataloguer et réunir les nombreux rapports publiés à ce jour concernant les expérimentations sur la PD et la dérive due au vent effectuées par la GCC et la USCG.

Ces travaux présenteraient un intérêt manifeste pour les chercheurs oeuvrant tant au sein de la GCC qu'à l'extérieur. On pourrait penser à réunir tous les rapports sur CD-ROM, y compris, dans la mesure du possible, les documents de référence.

5. Envisager l'instauration, par la Garde côtière canadienne, d'un programme d'établissement et de maintenance d'une base de données des types de radeaux de sauvetage et/ou d'embarcations de survie équipant les navires naviguant dans les eaux canadiennes.

Disposant de ces données, les coordonnateurs d'opérations de recherche-sauvetage pourraient mieux estimer la dérive due au vent et la dérive totale de ces embarcations et déterminer plus précisément la largeur de balayage. Ces travaux pourraient d'abord prendre la forme d'un projet-pilote régional, qui donnerait une idée de l'ampleur des travaux de catalogage nécessaires à l'échelle nationale et du travail exigé pour tenir à jour la base de données.

Essais de probabilité de détection

6. Lancer un projet-pilote d'utilisation du simulateur de navigation maritime de St. John's pour mener des essais de détection d'objets flottants.

Un tel projet permettrait de colliger des données de PD à un rythme accéléré. La principale objection à cette démarche pourrait s'exprimer ainsi : «Jusqu'à quel point est-il possible de simuler des conditions réelles?» Selon certains, les résultats d'une simulation n'auraient aucune valeur pratique. Mais on peut penser à une méthode permettant d'obtenir des résultats valables au terme d'une étude utilisant un simulateur de navigation. En voici les grandes lignes.

La démarche de base consisterait à comparer les résultats d'une simulation avec ceux d'un essai en mer réalisé dans des conditions connues. On dispose d'ores et déjà de vastes ensembles de données d'expérimentation, dans lesquels sont consignées tous les paramètres utiles pour la mise au point de scénarios de recherche. L'ensemble de données issu de l'expérience menée en 1990 au large du Banc de Canso portait sur des navires de recherche de la GCC et de la USCG. L'accès à ces données résout le problème de la validation et la question de la fidélité du simulateur. À partir des données d'essai, tous les paramètres de recherche peuvent être programmés dans le simulateur de navigation. Ces paramètres comprennent les circuits de recherche, la vitesse du navire, les conditions de houle, l'emplacement de la cible, le type de cible, etc. Les largeurs de balayage alors établies par le simulateur pourraient être étalonnées à l'aide des largeurs de balayage générées à la suite des essais en mer.

7. Poursuivre la collecte de données relatives à des recherches effectuées au moyen de radars de bord classiques, portant sur des cibles de petites dimensions, avec et sans réflecteurs radar.

Plusieurs ensembles de données restreints ont été constitués en 1995 ainsi que lors d'expériences antérieures remontant à 1986. Il importe de poursuivre ces travaux afin de pouvoir établir un seuil fiable de largeur de balayage pour un radar de bord classique utilisé pour la recherche de petites cibles flottantes. C'est que, même avec les nouvelles technologies, comme l'IMR et le pisteur IA, la plupart des navires sont encore équipés de radars utilisant des méthodes de traitement classiques.

8. Poursuivre la collecte de données de PD pour des technologies nouvelles, comme l'IMR et le pisteur IA, et établir des modèles de PD pour ces technologies appliquées à la détection de cibles de petites dimensions.

Ces nouvelles technologies ont montré des performances supérieures à celles des radars de bord classiques. Mais il reste à documenter de façon rigoureuse ces performances, par des essais comparatifs confiés à des chercheurs indépendants. Une démonstration claire de la supériorité de ces nouvelles technologies par rapport aux radars classiques pourrait faciliter la recherche d'appuis pour des travaux de R&D, non seulement au sein du gouvernement mais aussi dans le secteur privé, notamment l'industrie pétrolière.

9. Accentuer les travaux d'établissement de modèles de PD pour la recherche de petites cibles flottantes au moyen de LVN.

On trouve maintenant plus couramment des LVN à bord des navires de la GCC.

10. Poursuivre l'examen des recommandations touchant la collecte de données formulées à l'issue des deux premières phases du projet, et leur donner suite en concentrant les travaux sur les types de navires pour lesquels il existe déjà des ensembles de données de détection.

Le fait de combler les lacunes des ensembles de données d'essai obtenues pour les types de navires déjà étudiés permettra d'établir des largeurs de balayages pour des combinaisons plate-forme/cible/moyen de détection supplémentaires.

Essais de dérive due au vent

11. Lancer un projet visant l'élaboration de modèles de dérive due au vent pour certaines cibles flottantes courantes, et la validation de ces modèles par des essais en mer.

Des expériences menées en 1992 et 1993 en marge du projet sur la dynamique de la dérive due au vent ont permis la collecte d'ensembles de données qui ont servi à l'élaboration de modèles pour un radeau de sauvetage à 4 places et une embarcation de 5,6 m. Logiquement, la prochaine étape serait d'élaborer des modèles pour des cibles flottantes courantes au sujet desquelles on ne dispose encore d'aucune donnée. Ces modèles devraient ensuite être validés de façon indépendante au cours d'essais en mer. Si les modèles s'avéraient performants, cela accélérerait l'élaboration de modèles de dérive due au vent pour nombre de cibles flottantes courantes et, encore plus important, le coordonnateur des opérations de recherche-sauvetage pourrait les utiliser en toute confiance.

Ces essais en mer pourraient être réalisés en même temps que la collecte de données relatives à des recherches portant sur d'autres types de cibles flottantes.

12. Réexaminer les données de dérive due au vent de 1992 et 1993 pour déterminer l'effet des vagues sur la dérive d'une cible flottante.

Les expériences sur la dérive due au vent menées en 1992 et 1993 ont permis de colliger certaines données sur les vagues. Mais aucune tentative n'a été faite de déterminer précisément l'influence des vagues sur la dérive totale. Il peut en outre être intéressant de réexaminer d'autres questions, comme la composante vent traversier ou angle de dérive due au vent, au cours d'une plus longue période d'étude.

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1.0 INTRODUCTION

This document constitutes OCEANS Ltd.'s final report for the project entitled "**TARGET DETECTION EXPERIMENT – PHASE III – DATA ANALYSIS".**

Section 1 of the report provides the background for this multi-phase project as well as a review of the Phases I and II work. Section 2 covers the objectives and tasks specific to the Phase III work. Section 3 describes the methodologies used in each task and task results. Section 4 presents the data analysis results while section 5 presents the conclusions and recommendations of this Phase III work.

1.1 Background

This multi-phase project was 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. These 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 search and rescue (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 Canadian Coast Guard Ship (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 canopy lights and retro-reflective tape and without canopy lights. During radar searches some life rafts were outfitted with radar reflectors to represent persons on board.

Transport Canada has embarked on an effort to develop valid POD models by carrying out search experiments using free drifting objects. It is acknowledged that POD data will be collected at a slower rate using the free drifting target approach rather than the traditional fixed target approach because of the logistics and drift variability associated with a free drifting target array. However, POD data will be collected in more realistic search scenarios while allowing for data collection to support related research.

- Sea Keeping Performance of SAR Vessels;
- Radar-Based SAR Target Detection;
- Drift Errors in Search Modeling;
- Leeway Data Collection;
- CANSARP/CASP Evaluation; and,
- Human Factors.

1.2 Overall Project Objectives

The overall project objective was 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.

1.2.1 Phase I Objective: Experiment Planning

The objective of Phase I was to develop an experiment plan that would be used in future detection experiments conducted during the various phases of this project.

1.2.2 Phase II Objective: Full-Scale Experiment

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

1.2.3 Phase III Objective: Data Analysis

The objective of Phase III was 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 modeling.

1.3 Summary of Phase I Work

The objectives specific to the Phase I work were to develop an experiment plan that would 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.

The following paragraphs summarize the findings and recommendations contained in the Phase I final report.

<u>Recommended Data Collection Requirements</u>

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

TARGETS:

- Persons in the water (PIWs) in a variety of configurations;
- Four-person to 25-person orange life rafts in a variety of configurations; and,
- Small boats ranging from 4.9 to 9.1 m in a variety of configurations.

SENSORS/SEARCH TYPE:

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

EMERGING TECHNOLOGIES:

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

SEARCH PLATFORMS:

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

INDEPENDENT VARIABLES:

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

<u>Validation Trials</u>

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. Leeway data were also collected for two life raft configurations.

<u>Experiment Plan</u>

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

- Data Collection Methodology;

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

Recommendation for Phase II (SAR '95)

The following recommendations were made for the Phase II fall '95 detection experiment:

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

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

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

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

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

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

- Carry out searches using the TITAN system.

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

- 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.

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

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

- 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.

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

1.4 Summary of Phase II Work

The objectives specific to Phase II evolved as a result of the Phase I recommendations and through discussions and meetings with various groups and agencies throughout the course of the Phase II project.

Phase II Primary Objectives

- Collect nighttime POD data for Night Vision Goggles (NVGs) against life rafts outfitted with retro-reflective tape.
- Collect daytime POD data for visual (binoculars) against orange canopied life rafts (4-20 person) and small white boats (16′-20′).
- Collect POD data for conventional radar against life rafts with radar reflectors simulating persons on board and small boats with radar reflectors.
- Collect daytime POD data for visual (binoculars) against Persons in the Water (PIWs) wearing orange survival suits.
- Collect nighttime POD data for NVGs against PIWs outfitted with retro-reflective tape.
- Collect POD data for conventional radar against PIWs.
- Conduct POD data reduction necessary for POD analysis.

Phase II SECONDARY OBJECTIVES

- Collect leeway data on boats and life rafts.
- Conduct deployment and recovery of a new GPS-EPIRB (Global Positioning System - Emergency Position Indicating Radio Beacon) to support operational tests.
- Provide vessel position information to Raytheon Canada Ltd. to support their Over the Horizon (OTH) radar tests.
- Use the Modular Radar Interface (MRI) to record real-time radar data during radar searches.
- Collect POD data using the TITAN radar display system.
- Collect data during the Fall '95 SAR trials that will assist in the CANSARP validation project.

Phase II Field Trials

The field experiment for Phase II took place on the Grand Banks of Newfoundland and in Conception Bay, Newfoundland from November 23rd to December 13th, 1995. The vessels involved in the field experiment were the Canadian Coast Guard Ship (CCGS) Sir Humphrey Gilbert and the Motor Vessel (MV) Nain Banker. The targets of interest were life rafts, small boats and PIWs.

Above normal conditions were experienced offshore throughout the field trials. The sea conditions seriously affected search activity and deployment/recovery operations.

Summary of Phase II Results

- In total 27 searches were conducted during the 1995 field trials for life rafts, small boats and PIWs. Searches were conducted from the MV Nain Banker and the CCGS Sir Humphrey Gilbert. The sensors included binoculars during day time, NVGs and radar.

- POD data was collected for 12 platform/target/sensor combinations (search types).

- Leeway data was collected on three (3) SAR targets in the normal and swamped condition yielding six (6) leeway configurations.

- Track data was obtained for seven (7) life rafts and two (2) boats in both the normal and swamped condition for input into the CANSARP validation project. As well, track data was collected for numerous PIW tracks in Conception Bay.

Summary of Phase II Conclusions

- Environmental conditions seriously impacted on data collection efforts during the trials. Due to environmental conditions the latter part of the trials were moved to Conception Bay where initial data sets were collected on PIWs.

- Lookouts on board the MV Nain Banker found the Litton Model M-972 NVGs to be more suitable for searching than the "Night Mariner" NVGs.

- The use of drifting SAR targets for detection experiments resulted in data collection to support related SAR research. However, trying to collect leeway data on five (5) targets may have been too ambitious for the time of year.

- For the data set collected, the Sperry 4016 radar provided promising results against small boats outfitted with radar reflectors.

- For the data set collected, the TITAN system provided promising results against life rafts with simulated persons on board and PIWs. The TITAN system was not tested against small boats.

- For the data set collected, there were no NVG detections for PIWs outfitted with retro-reflective tape.

- For the data set collected, the detection rate for PIWs during daylight visual searches was approximately 40% for opportunities in the 0-1 nmi lateral range bin.

<u>Data Analysis Recommendations for Phase III</u>

- Perform POD analysis on the following data sets for the purposes of getting a preliminary measure of sweep width:

    - daylight visual for PIWs;
    - 4016 Radar for PIWs;
    - 4016 Radar for boats and life rafts;
    - TITAN display system for PIWs; and,
    - MRI/AI Tracker for life rafts and PIWs.

- Perform leeway analysis on the leeway data collected during the 1995 experiment.

- Use SAR target tracks obtained during the 1995 trials for input into CANSARP validation.

2.0 PHASE III OBJECTIVES AND TASKS

The following are the main objectives specific to this Phase III project.

- Conduct on an inventory of all available marine SAR POD data sets, Canadian and U.S.
- Merge the data sets into one data base.
- Provide a POD calculation and analysis tool as part of the data base.
- Conduct a data analysis using the newly constructed data base.
- Produce a Final Report

2.1 Task 1: Work Plan

This task involved preparing a detailed project work plan that included a review of the project objectives, a list of reference documents, a summary of project tasks, a project schedule, management and control procedures and a list of project participants and personnel co-ordinates. As part of the work plan a detailed Software Development Plan (SDP) was to be developed to govern the software development process. The work plan document was to serve as a project summary for OCEANS Ltd. and the Project Officer, Charles Gautier, to quickly locate information about the project.

2.2 Task 2: Data Base Inventory

The first requirement of this task was to complete an inventory of all available SAR detection data sets. The inventory was to comprise the nature of the data, the various elements of information contained in each data set, the availability of the data set (i.e., whether special permission was required, etc.), the format of the data set and whether external data could be recovered to complement the data set (such as environmental data at the time the data was collected). The key sources of the data were to be OCEANS Ltd., the CCG, the USCG R&D Center and USCG contractors (e.g., Analysis and Technology).

2.3 Task 3: Data Base Design

From the information provided by the data base inventory a data base structure would be developed. The data base structure would provide the framework for the integration of all past and current data sets into a unified data base structure. This unified data base structure was to include the following:

- the development of formats for unprocessed field data;
- a format for the processed data necessary for input into POD analysis; and,

- a format for the processed data necessary for input into Leeway analysis.

2.4 Task 4: Data Base Construction

Following the finalizing of the data base structure and formats, construction of the data base would involve the entry of the various data sets into specified formats. Unprocessed field data was to be entered in Excel format while processed data to be used for input into the POD analysis was entered into Excel format as well as Microsoft Access format. Validation of the data was to be carried out both by visual inspection of the data and by the comparison of analysis results using the unified data base with SARDAS and comparing results against those results obtained in past experiments.

2.5 Task 5: Development of SAR Data Analysis Software (SARDAS)

In addition to defining and constructing a unified data base, TDC requested that the data base construction also include a SAR Data Analysis Software (SARDAS) package that would be able to interface with both the developed unified data base and the multi-linary regression model (logodds) used in POD analysis.

2.6 Task 6: Data Analysis

Following the development and construction of the unified data base and parallel development of SARDAS, POD data analysis was to be conducted on all collected data sets. All possible POD curves were to be produced, along with inference as to the level of confidence and accuracy of the curves.

In addition to the above, requirements for future POD data collection were to be identified. The POD data collection requirements was to include a list of all existing POD curves, the confidence level associated with these data sets and identification of future data collection requirements necessary to achieve appropriate confidence levels in the existing data sets.

3.0 PROJECT TASK METHODOLOGIES AND RESULTS

The following sub-sections describe the methodologies used in each of the identified tasks together with the results and findings associated with each task as appropriate.

3.1 Task 1: Work Plan

The Work Plan which was described in section 2.1 was submitted to the Project Authority in February 1997 and was the subject of the project kick-off meeting.

3.2 Task 2: Data Base Inventory

3.2.1 Methodology

The following steps describe the methodology used in creating the data base inventory:

- Canadian and American POD reports dating back to 1986 were reviewed.

- A search was carried out of the hard copy and electronic files residing at OCEANS Ltd. to identify the various data sets that were available. Similarly the USCG was contacted and asked to provide whatever data they had available.

- The available data sets were reviewed and a table was created that logically separated and identified the data.

- The data formats of each of the identified data sets were documented.

3.2.2 Results

The results of Task 2 were submitted to the Project Authority during the summer of 1997. The document was entitled "SAR Data Inventory Report". The following is contained in the report:

- The POD data inventory from CCG and USCG searches dating back to 1986.

- POD data formats from past experiments.

- Proposed future POD data formats.

- Leeway data inventory.

3.3 Data Base Design

3.3.1 Methodology

The design of the data base followed from the data base inventory. The methodology for designing the data base was as follows:

- The format of field logs from past experiments were documented and reviewed.

- The format of the input data used in POD modeling was documented and reviewed.

- A set of parameters for input into POD modeling was established. This data set came to be known as the CPA (Closest Point of Approach) data set.

- The format of each of the parameters contained in the CPA data set was established.

- Finally, the parameters required to create the CPA data set were logically divided into appropriate field logs. The format of the parameters contained in the field logs were for the most part the same as those contained in the CPA data set.

3.3.2 Results

The data base design resulted in designing and formatting of the following field data collection sets (raw data) and the input data set (processed data):

<u>Field Data Collection Sets</u>

Visual detection data;
Radar detection data;
Environmental data;
Human factor data;
Search track data;
Target status data; and,
Target track data.

<u>Processed Data Set</u>

CPA data.

A full description of the field data collection sets is given in the document entitled "USER GUIDE for SARDAS V1.0Beta". The CPA data format is described in appendix 2 of the USER GUIDE and is referred to as the Input Data Base Structure. The USER GUIDE was submitted to the Project Authority in June of this year as was a CD that contained the USER GUIDE as well all the data assembled under this project as well as all data format descriptions.

3.4 Data Base Construction

All hard copy data was entered into the newly designed data set formats using Microsoft Excel while electronic data was converted into excel files from their ascii format and copied into the newly designed format.. All the newly formatted data is contained on CD which has been provided as part of this report. The data directory structure is shown in appendix 4 of the USER GUIDE. CPA data sets were additionally copied and formatted into Microsoft Access where these data were assembled into one file that constituted the data base file used by the SAR Data Analysis Software (SARDAS). The data base inventory is shown in Table 3.1.

Quality assurance of the newly formatted data involved a visual review of the data as well as a comparison of model results based on the newly created data base compared to published results from original data sets.

3.5 SAR Data Analysis Software (SARDAS)

For part of the unified data base construction, TDC requested that a SAR Data Analysis Software (SARDAS) package be included that would be able to interface with both the developed unified data base and the multi-linary regression model (logodds) used in POD analysis.

The methodology used in the development of this software is described in a series of reports previously submitted during the project. These include the Project Work Plan, the SARDAS User Guide and the Software Requirement Specifications.

The result of our efforts has been the creation of SARDAS V1.0. Commercial-Off-The-Shelf (COTS) statistical software packages containing the regression algorithm required for the modeling of POD data sets have existed since the mid 1980s (e.g., SYSDAT® with the LOGIT® extension module). Other custom applications for performing this analysis have also been developed by the CCG, USCG and their private industry contractors. The primary advantages of SARDAS V1.0 as compared to these other options are its Windows 95® point-and-click, user-friendly interface and the capability to generate POD models, corresponding POD curves, and sweep width calculations within a single software interface.

In addition to its POD modeling and analysis capabilities, SARDAS V1.0 enables the analyst to quickly compute basic statistics for the independent variables such as mean, minimum, maximum, and standard deviation. Three-dimensional histograms can also be created to show the distribution of each variable across lateral range bins. These statistical features help the analyst to characterise the data to determine which variables are appropriate/ inappropriate for incorporation into a particular POD model.

SEARCH TYPE				POD MODELING DATA	ASSEMBLED FIELD DATA SETS					
1 YEAR	2 SRU	3 SENSOR	4 TARGETS	5 CPA (records)	6 DETECT	7 ENV	8 HUMAN FACTOR	9 SEARCH TRACKS	10 TARGET STATUS	11 TARGET TRACKS
1986	Jackman	Day Visual	4-person orange life rafts	76	X	X		X		X
		Sperry 127E Radar	4-person life rafts with & without radar reflectors.	72	X	X		X		X
	USCG WPB	Day Visual	Hand-held orange smoke flares	117						
	USCG UTB			50						
	USCG WPB	Night Visual	White strobe	27						
	USCG UTB			309						
	USCG WPB		Hand-held red flare	211						
	USCG UTB			278						
1987	Sir William Alexander	Day Visual	4-6-person orange & yellow life rafts	585	X	X		X		X
1988	King Air B200	APS-504(V)5	4-6-person life rafts with radar reflectors	189	X	X		X		X
	Alert Bridge	Day Visual	4-6-person orange life rafts	70	X	X		X		X
		Night Visual	4-6-person life rafts with canopy lights	18	X	X		X		X
	Sir William Alexander Flying Bridge	Day Visual	4-6-person orange life rafts	32	X	X		X		X
1989	USCG 41′ Utility Boats	Night Vision Goggle	PIWs with reflective tape	239						
			5.5-6.4 m boats	132						
			4-9 person life rafts without reflective tape	190						

Table 3.1: Data Base Inventory

SEARCH TYPE				POD MODELING DATA	ASSEMBLED FIELD DATA SETS					
1 YEAR	2 SRU	3 SENSOR	4 TARGETS	5 CPA (records)	6 DETECT	7 ENV	8 HUMAN FACTOR	9 SEARCH TRACKS	10 TARGET STATUS	11 TARGET TRACKS
1990	King Air B200	APS-504(V)5	4-6-person life rafts with radar reflectors	128		X				X
	Alert Bridge	Day Visual	4-6-person orange & yellow life rafts	287	X	X	X	X		X
	Alert Flying Bridge			44	X	X	X	X		X
	Alert Bridge	Night Vision Goggles	4-6-person life raft canopy lights	184	X	X	X	X		X
			4-6-person life rafts with reflective tape	36	X	X	X	X		X
	CCRS Convair 580	C/X SAR	4-6-person life rafts with radar reflectors	82		X				X
	Vigorous Bridge	Day Visual	4-6-person orange and yellow life rafts	375	X	X	X	X		X
	Vigorous Flying Bridge			365	X	X	X	X		X
	Vigorous Bridge	Night Vision Goggles	4-6-person life raft canopy lights	118	X	X	X	X		X
	Vigorous Flying Bridge			110	X	X	X	X		X
	Vigorous Bridge		4-6-person life rafts with reflective tape	55	X	X	X	X		X
	Vigorous Flying Bridge			38	X	X	X	X		X
	USCG UTB		5.5-6.5 m boats	64						
			PIWs with red safety lights	25						
			4-6-person life rafts with reflective tape	134						
			4-6-person life rafts without reflective tape	27						

Table 3.1: Data Base Inventory (Cont'd)

SEARCH TYPE				POD MODELING DATA	ASSEMBLED FIELD DATA SETS					
1 YEAR	**2 SRU**	**3 SENSOR**	**4 TARGETS**	**5 CPA (records)**	**6 DETECT**	**7 ENV**	**8 HUMAN FACTOR**	**9 SEARCH TRACKS**	**10 TARGET STATUS**	**11 TARGET TRACKS**
1994	Bickerton	Day Visual	4-6-person orange life rafts	70	X	X	X	X		X
1995	Nain Banker	Day Visual	PIWs in orange survival suits, 4-6-20 person life rafts and 6 m boats	66	X	X	X	X	X	X
		Night Vision Goggles	PIWs & 4-6-20 person life rafts with reflective tape	40	X	X	X	X	X	X
	Sir Humphrey Gilbert	Sperry 4016 radar	4-6-20 person life rafts and 6m boats with radar reflectors	40	X	X	X	X	X	X
			Swamped life rafts	36	X	X	X	X	X	X
			PIWs	63	X	X	X	X	X	X
		TITAN	4-6-20 person life rafts with radar reflectors	11	X	X	X	X	X	X
			PIWs	24	X	X	X	X	X	X

Table 3.1: Data Base Inventory (Cont'd)

3.6 Probability of Detection (POD) Analysis

3.6.1 Introduction

The methodology employed for the analysis of the visual and night vision goggle search data was the same as that used in the previous CCG/TDC experiments 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 3.1 illustrates the concept of sweep width.

3.6.2 Data Reduction Methodology

The data reduction for the search data collected during the 1995 trials was carried out as part of the Phase II project. The data reduction process conducted on the 1995 data was essentially the same process that was carried out on search data during previous experiments.

Data reduction is essentially determining all the valid detection opportunities for each search type and assigning the various independent variables applicable at the time to the detection opportunity. The time assigned to the detection opportunity is the time of the CPA of the target to the search vessel. A target is considered a valid opportunity when it falls within the range of the detector. As an example, the visual horizon of the MV Nain Banker is approximately 6 nmi for targets having a height 1 m or less. Therefore, all targets with a CPA of 6 nmi or less would be considered valid detection opportunities during a visual search from the MV Nain Banker. An exception to this would be a target with a CPA beyond the prevailing visibility. For example, if the prevailing visibility is 2 nmi at the time of CPA for a selected target and the CPA of the target is beyond 2 nmi, then this target would not be considered a valid detection opportunity. Data for the independent variables were collected during the search trials through a number of data collection activities that can be summarized in the following categories:

- target detection data;
- environmental data;
- human factor data;
- SRU data; and,
- target status data.

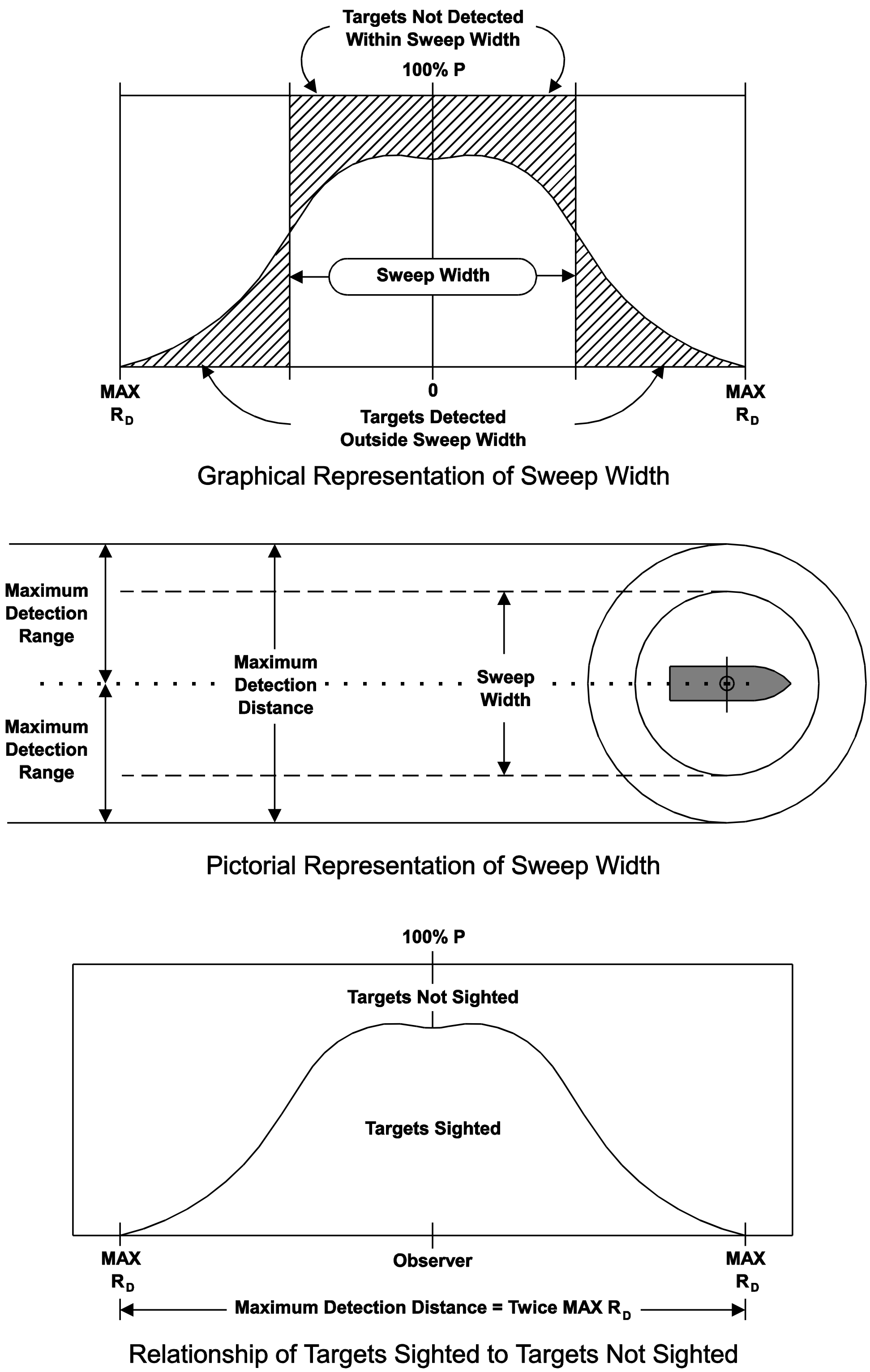

Figure 3.1: Concept of Sweep Width

To determine whether a detection opportunity has been detected, each search was replayed using OCEANS Ltd. search simulation program. The simulation animated the tracks of the search vessel and SAR targets. When a detection was noted the animation was stopped at the time of detection. The analyst then entered the range and bearing of the target as entered in the detection log. The program then plotted the detection on the screen and the analyst determined whether the detection was valid or not. If the detection was not valid this was recorded as a false detection. If the detection was valid, a detection mark is assigned to the corresponding detection opportunity. In summary, the following steps were carried out in the POD data reduction process for the 1995 data:

1. Determined target status (upright, swamped, overturned);

2. Compiled all valid opportunities for each search type (daylight visual, NVG, Sperry 4016 radar, MRI, and TITAN);

3. Compiled and confirmed all target detections for each search type;

1. Assigned the relevant variables to each detection opportunity for each search type; and,

2. Finalized assembly of POD analysis files by search type.

3.6.3 Data Analysis Methodology

The primary application of SARDAS V1.0 is the analysis of SAR detection data to determine a mathematical relationship between POD and the independent variables affecting detection (i.e., search platform characteristics, sensor characteristics, target variables, environmental conditions, and human factors). SARDAS accomplishes this task by utilizing a multivariate logistic regression algorithm developed by Cox (1970) to fit the available data to an equation of the following form:

$$POD \quad \frac{1}{1 \quad e} \qquad \text{Eqn. (1)}$$

where,

$$a_o \quad {}_{i\ 1}^{\ n} \; a_i x_i \qquad (2)$$

and,

a_o is a constant;
a_i is the coefficient of the *i*th independent variable;
x_i is the value of the *i*th independent variable; and
n is the number of independent variables.

The above equation is based on the lateral range distribution derived by Koopmans (1980). The SARDAS V1.0 modeling algorithm can consider up to 20 independent variables in its analysis, as selected by the user (analyst) from the program's source data base. The software can accept any data which are describable as either continuous (e.g., wind speed, wave height, etc.), binary (e.g., 1=on/yes, 0=off/no), or as discrete numerical values where a representative relationship between numerical values and the independent variables can be defined (e.g., changes in artificial light level can be assigned representative numeric values: 0=rural/ofshore, 1=suburban and 2=urban; an ascending numerical value represents increasing lighting conditions). All selected data are automatically converted to representative numerical values at the time of the analysis. The program's regression analysis engine then attempts to develop a model for each and every combination of the independent variables being considered. For all combinations which converge to a solution, variables are checked for statistical significance at a 90% confidence interval. Models for which all variables are statistically significant are considered possible optimum models are put forth for review by the analyst to determine the appropriate model.

Having determined an appropriate POD model for a given platform/ sensor/target combination, SARDAS V1.0 was used to calculate corresponding POD model curves and sweep width values. The POD model curve is a graph of POD as a function of the target's lateral range, obtained by setting all other independent variables in equation (1) to fixed conditions. This produces a two-dimensional curve defined by an equation of the following form:

$$POD(x_{lr}) \quad \frac{1}{1 \quad e^{\quad (x_{lr})}} \qquad (3)$$

where,

x_{lr} is the target's lateral range.

Once the POD model curve is defined, the corresponding optimal search sweep width, SW, is simply calculated as twice the area beneath the POD curve, as defined by the following equation:

$$SW \quad \int_{0} POD(x_{lr})dx_{lr} \quad \int_{0} \frac{1}{1 \quad e^{\quad (x_{lr})}} dx_{lr} \qquad (4)$$

4.0 DATA ANALYSIS RESULTS

Sub-sections 4.1 to 4.7 present an analysis of individual data sets from 1986–1995 that were assembled as part of this project (see Table 3.1). Sub-section 4.8 presents a number of analyses for combined data sets for common SAR targets and sub-section 4.9 provides POD curves for these combined data sets. Sub-section 4.10 provides a review of POD models for those data sets collected in 1995 for which a model result was obtained. Sub-section 4.11 presents a summary of sweep width calculations for the various search types for which data has been assembled in this project.

Each analysis contains the following parameters:

- Model input data - averages, standard deviations, minimums, and maximums;
- Target detections versus target opportunities;
- The POD model which consists of significant variables and their coefficients; and,
- Sample sweep width calculations for selected conditions contained within the data set being analyzed.

Sample sweep width calculations will generally represent poor, average, and good conditions represented in the data set. When the only significant variable is lateral range the sample sweep width will represent the average conditions contained in the data set. Where no solution is obtained from the logodds model for certain radar data sets an estimate of the sweep width is given.

The logodds model used to generate POD coefficients is designed for visual type searches. However, during the course of the analysis the logodds model arrived at a result for certain radar detection data sets. Those radar data sets for which a result was achieved typically exhibited a POD decreasing with lateral range.

4.1 Analysis of Individual Data Sets for 1986

4.1.1 CCGS Jackman – Day Visual – 4-Person Orange Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.75	1.55	0.02	6.58
SRU Speed	9.55	0.15	9.50	10.00
Visibility	7.19	6.35	0.13	15.00
Wind Speed	12.46	5.37	2.00	25.00
Wave Height	1.09	0.35	0.40	1.90

Detections: 32 Opportunities: 76

POD Model:

Significant Variables	Coefficients
Constant	-0.869008
CPA/Lateral Range	-0.784917
Visibility	0.266728

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Visibility	1 nmi	7 nmi	12
Sweep Width	1.1 nmi	3.4 nmi	6.2 nmi

4.1.2 CCGS Jackman - Sperry 127E Radar - 4-Person Life Rafts Without Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.17	0.77	0.02	2.96
SRU Speed	9.66	0.24	9.50	10.00
Visibility	1.06	3.00	0.13	15.00
Wind Speed	11.55	6.45	2.00	25.00
Wave Height	0.88	0.18	0.40	1.10

Detections: 7 Opportunities: 27

POD Model:

Significant Variables	Coefficients
Constant	1.32
CPA/Lateral Range	-4.07

Sweep Width Calculations

For average conditions:	Sweep Width = 0.76 nmi

4.1.3 CCGS Jackman"- Sperry 127E Radar - 4-Person Life Rafts with Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.26	0.91	0.10	3.31
Visibility	4.79	5.46	0.13	15.00
Wind Speed	13.95	6.52	2.00	25.00
Wave Height	1.24	0.49	0.40	1.90

Detections: 12 Opportunities: 45

POD Model:

No model solution. Estimated Sweep Width = 2.7 nmi

4.1.4 USCG Work Patrol Boat (WPB) - Day Visual - Hand-Held Orange Smoke Flares (HHOS)

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.58	1.92	0.40	9.20
Wind Speed	4.62	2.85	2.00	9.00
Wave Height	0.54	0.05	0.50	0.60
Relative Sun Azimuth	1.03	0.41	0.00	2.00
Sun Elevation	62.39	4.65	50.00	68.00
Operator Time on Task	1.93	1.34	0.00	4.00

Detections: 46 Opportunities: 117

POD Model:

Significant Variables	Coefficients
Constant	6.267184
CPA/Lateral Range	-1.704362
Operator Time on Task	-0.799276

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Time on Task	3 hours	2 hours	1 hour
Sweep Width	4.6 nmi	5.6 nmi	6.4 nmi

4.1.5 USCG 41′ Utility Boats (UTBs) - Day Visual - HHOS

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	2.94	1.82	0.30	6.90
Visibility	9.36	1.79	1.00	10.00
Wind Speed	4.82	1.32	1.00	7.00
Wave Height	0.54	0.13	0.30	1.10
Relative Sun Azimuth	1.16	0.46	0.00	2.00
Sun Elevation	56.32	6.28	44.00	64.00
Operator TOT	0.76	0.82	0.00	3.00

Detections: 20 Opportunities: 50

POD Model:

Significant Variables	Coefficients
Constant	5.664425
CPA/Lateral Range	-2.357985
Operator Time on Task	-0.868693

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Time on Task	3 hours	2 hours	1 hour
Sweep Width	2.7 nmi	3.4 nmi	4.1 nmi

4.1.6 USCG WPBs and UTBs – Night Visual – PIW Life Ring White Strobes

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.73	1.26	0.00	5.00
SRU Speed	14.91	0.27	14.00	15.00
Cloud Cover	6.06	3.22	2.00	10.00
Visibility	10.84	5.73	5.00	20.00
Wind Speed	9.23	4.76	4.00	15.00
Wave Height	0.76	0.29	0.30	1.10
Operator TOT	0.82	0.95	0.00	4.00

Detections: 155 Opportunities: 336

POD Model:

Significant Variables	Coefficients
Constant	4.128528
CPA/Lateral Range	-1.523534
Wind Speed	-0.133197
Operator Time on Task	-0.814994

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Wind Speed Time on Task	15 kn 3 hours	9 kn 2 hours	6 kn 1 hour
Sweep Width	0.7 nmi	2.0 nmi	3.4 nmi

4.1.7 USCG WPBs – Night Visual – Hand-Held Red Flares (HHRF)

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.03	2.30	0.30	9.70
Cloud Cover	2.42	2.44	0.00	10.00
Visibility	8.45	1.26	6.00	10.00
Wind Speed	6.83	4.39	3.00	20.00
Wave Height	0.47	0.20	0.30	0.80
Operator TOT	1.51	1.23	0.00	4.00

Detections: 165 Opportunities: 211

POD Model:

Significant Variables	Coefficients
Constant	6.139037
CPA/Lateral Range	-0.913747
Operator Time on Task	-0.176956

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Time on Task	3 hours	2 hours	1 hour
Sweep Width	12.4 nmi	12.7 nmi	13.1 nmi

4.1.8 USCG UTBs – Night Visual - HHRF

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.97	2.18	0.20	9.00
SRU Speed	14.62	0.99	12.00	15.00
Cloud Cover	1.39	0.82	0.00	3.00
Visibility	9.59	2.41	6.00	15.00
Wind Speed	5.90	2.25	3.00	10.00
Wave Height	0.44	0.16	0.30	0.80
Operator Time on Task	1.21	1.26	0.00	4.00

Detections: 188 Opportunities: 278

POD Model:

Significant Variables	Coefficients
Constant	5.103605
CPA/Lateral Range	-0.953835
Operator Time on Task	-0.096155

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Time on Task	3 hours	2 hours	1 hour
Sweep Width	10.2 nmi	10.4 nmi	10.6 nmi

4.2 Analysis of Individual Data Sets for 1987

4.2.1 CCGS Sir William Alexander – Bridge – Day Visual - 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.32	1.95	0.02	6.94
Target Type	0.36	0.00	0.00	1.00
Cloud Cover	6.63	3.33	0.00	10.00
Visibility	13.88	2.25	5.00	15.00
Precipitation	0.08	0.27	0.00	1.00
Wind Speed	20.04	8.14	2.00	43.00
Wave Height	1.55	0.41	0.60	2.50
White Caps	1.07	0.70	0.00	2.00

Detections: 176 Opportunities: 585

POD Model:

Significant Variables	Coefficients
Constant	0.966454
CPA/Lateral Range	-1.182955
Target Type	0.901303
Visibility	0.210553
Wave Height	-1.285928

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Target Type Visibility Wave height	4-person raft 5 nmi 2.5 m	4- and 6-person rafts 10 nmi 1.5 m	6-person rafts 15 nmi 0.5 m
Sweep Width	.45 nmi	2.8 nmi	7.2 nmi

4.3 Analysis of Individual Data Sets for 1988

4.3.1 King Air B200 - APS-504(V)5 Airborne Search Radar - 4- and 6-Person Life Rafts with Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	7.67	5.34	0.02	22.64
Target Type	0.22	0.00	0.00	1.00
Visibility	13.66	2.52	8.00	15.00
Wind Speed	22.79	7.68	12.00	34.00
Wave Height	2.13	0.72	1.20	3.00
White Caps	1.12	0.78	0.00	2.00

Detections: 29 Opportunities: 189

POD Model:

No model solution. Estimated Sweep Width = 5.25 nmi.

4.3.2 CCGS Alert - Bridge - Daylight Visual - 4- and 6-Person Orange Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.09	2.50	0.08	9.83
Target Type	0.31	0.00	0.00	1.00
Cloud Cover	5.31	2.71	3.00	10.00
Visibility	13.35	3.26	5.00	15.00
Precipitation	0.08	0.28	0.00	1.00
Wind Speed	25.71	3.93	18.00	31.00
Wave Height	2.45	0.22	2.00	2.70
White Caps	1.74	0.44	1.00	2.00

Detections: 23 Opportunities: 70
POD Model:

Significant Variables	Coefficients
Constant	8.397330
CPA/Lateral Range	-2.295719
Visibility	0.410576
Wind Speed	-0.410816

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Visibility Wind Speed	8 nmi 30 kn	10 nmi 25 kn	12 nmi 20 kn
Sweep Width	.37 nmi	2.0 nmi	4.5 nmi

4.3.3 CCGS Alert – Bridge – Night Visual - 4- and 6-Person Life Raft Canopy Lights

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	2.78	2.48	0.04	7.47
Target Type	0.22	0.00	0.00	1.00
Cloud Cover	8.16	1.50	6.00	10.00
Visibility	6.66	2.92	0.25	8.00
Precipitation	0.33	0.97	0.00	3.00
Wind Speed	34.27	2.73	30.00	39.00
Wave Height	3.13	0.13	2.80	3.20
Water Temperature	2.97	0.06	2.80	3.00

Detections: 2 Opportunities: 18

POD Model:

No model solution. Estimated Sweep width = 0.66 nmi

4.3.4 CCGS Sir William Alexander – Flying Bridge - Daylight Visual - 4- and 6-Person Orange Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	2.61	2.19	0.54	9.61
Target Type	0.21	0.00	0.00	1.00
SRU Speed	13.10	0.22	12.90	13.60
Cloud Cover	5.00	1.95	2.00	7.00
Wind Speed	23.18	6.85	15.00	34.00
Wave Height	1.94	0.34	1.60	2.40
White Caps	1.31	0.82	0.00	2.00
Relative Humidity	78.93	6.83	69.00	88.00
Air Temperature	-0.37	2.62	-3.40	2.40
Water Temperature	5.37	0.29	5.00	6.00

Detections: 13 Opportunities: 32

POD Model:

Significant Variables	Coefficients
Constant	7.707244
CPA/Lateral Range	-1.824610
Wind Speed	-0.193287

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Wind Speed	30 kn	23 kn	15 kn
Sweep Width	2.2 nmi	3.6 nmi	5.2 nmi

4.4 Analysis of Individual Data Sets for 1989

4.4.1 USCG UTBs – NVGs – PIWs with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.27	0.14	0.00	0.60
Sensor Description	0.27	0.00	0.00	1.00
SRU Speed	15.36	1.90	10.00	20.00
Cloud Cover	0.50	2.18	0.00	10.00
Visibility	11.70	4.97	2.00	15.00
Wind Speed	8.93	5.46	3.00	22.00
Wave Height	0.66	0.22	0.40	1.10
White Caps	0.54	0.74	0.00	2.00
Relative Swell Direction	0.99	0.53	0.00	2.00
Relative Humidity	81.75	3.43	74.00	90.00
Air Temperature	15.29	4.87	11.50	24.50
Water Temperature	16.41	4.16	13.20	24.00
Moon Visibility	0.06	0.24	0.00	1.00
Moon Relative Azimut	1.00	0.65	0.00	2.00
Moon Elevation	-24.95	25.17	-65.00	46.00
Moon Phase	1.35	0.67	1.00	4.00
Operator Time on Task	1.56	1.46	0.00	6.00

Detections: 14 Opportunities: 239

POD Model:

Significant Variables	Coefficients
Constant	-0.933450
CPA/Lateral Range	-9.657593

Sweep Width Calculations

For average conditions:	Sweep Width = .07 nmi

4.4.2 USCG UTBs – NVGs - 5.5 and 6.4 m Boats

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.58	0.41	0.00	2.00
Target Type	0.42	0.00	0.00	1.00
Sensor Description	0.00	0.00	0.00	1.00
SRU Speed	15.44	2.63	9.00	20.00
Cloud Cover	3.76	3.94	0.00	10.00
Visibility	10.18	3.98	1.50	15.00
Wind Speed	8.97	4.66	2.00	20.00
Wave Height	0.80	0.23	0.40	1.30
White Caps	0.92	0.78	0.00	2.00
Relative Humidity	84.59	6.74	64.00	96.00
Air Temperature	17.47	4.60	5.50	24.30
Water Temperature	17.66	3.89	13.40	24.20
Moon Visibility	0.29	0.45	0.00	1.00
Moon Relative Azimut	1.00	0.52	0.00	2.00
Moon Elevation	-10.43	31.75	-60.00	51.00
Operator Time on Task	2.00	1.42	0.00	6.00

Detections: 16 Opportunities: 132

POD Model:

Significant Variables	Coefficients
Constant	3.878361
CPA/Lateral Range	-14.297721
Target Type	3.127102
Wave Height	-5.042462

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Target Type Wave Height	5.5 m boats 1 m	5.5 & 6.4 m boats 0.8 m	6.4 m boats 0.4 m
Sweep Width	0.04 nmi	0.2 nmi	0.7 nmi

4.4.3 USCG UTBs – NVGs - 4- and 6-Person Life Rafts without Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.50	0.29	0.00	1.00
Sensor Description	0.00	0.00	0.00	1.00
SRU Speed	14.68	1.50	9.00	17.00
Cloud Cover	3.54	4.09	0.00	10.00
Visibility	11.13	4.58	1.50	15.00
Precipitation	0.08	0.34	0.00	2.00
Wind Speed	9.67	3.84	2.00	24.00
Wave Height	0.78	0.27	0.40	1.40
White Caps	0.73	0.72	0.00	2.00
Relative Humidity	86.63	8.34	64.00	100.00
Air Temperature	16.24	4.63	6.10	24.00
Water Temperature	17.79	3.07	13.50	23.60
Moon Visibility	0.03	0.18	0.00	1.00
Moon Relative Azimut	1.00	0.59	0.00	2.00
Moon Elevation	-28.27	18.60	-62.00	33.00
Operator Time on Task	1.83	1.50	0.00	6.00

Detections: 17 Opportunities: 190

POD Model

Significant Variables	Coefficients
Constant	0.376915
CPA/Lateral Range	-9.925763

Sweep Width Calculations

For average conditions:	Sweep Width = .18 nmi

4.5 Analysis of Individual Data Sets for 1990

4.5.1 King Air B200 - APS-504(V)5 Airborne Search Radar - 4- and 6-Person Life Rafts with Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	6.82	4.51	0.08	18.59
Target Type	0.37	0.00	0.00	1.00
Target Radar Enhancement	0.62	0.00	0.00	1.00
Wind Speed	14.74	5.64	7.00	22.00
Wave Height	1.27	0.36	0.90	1.90
White Caps	0.62	0.48	0.00	1.00

Detections: 29 Opportunities: 128

POD Model:

Significant Variables	Coefficients
Constant	4.349455
CPA/Lateral Range	-0.278190
Wind Speed	-0.322678

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Wind speed	20 kn	15 kn	10 kn
Sweep Width	0.8 nmi	3.4 nmi	10.0 nmi

4.5.2 CCGS Alert – Bridge – Daylight Visual - 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.23	2.77	0.04	9.98
Target Type	0.45	0.00	0.00	1.00
SRU Roll	2.66	1.78	0.00	6.00
Cloud Cover	9.63	0.77	7.00	10.00
Visibility	9.51	4.33	1.50	15.00
Precipitation	0.03	0.17	0.00	1.00
Wind Speed	20.05	8.08	4.00	34.00
Wave Height	1.56	0.66	0.70	2.70

White Caps	1.25	0.84	0.00	2.00

Detections: 107 Opportunities: 287

POD Model:

Significant Variables	Coefficients
Constant	-5.289110
CPA/Lateral Range	-2.802397
Target Type	1.305488
Cloud Cover	1.209334
Visibility	0.183192
White Caps	-0.601642

Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Target Type Cloud Cover Visibility White Caps	4-person raft 7/10 6 nmi Many	4- and 6-person rafts 9/10 9 nmi Some	6-person raft 10/10 12 none
Sweep Width	2.2 nmi	5.2 nmi	7.4 nmi

4.5.3 CCGS Alert – Flying Bridge – Daylight Visual - 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.98	2.59	0.28	9.60
Target Type	0.40	0.00	0.00	1.00
Target Colour	0.90	0.00	0.00	1.00
SRU Roll	2.32	0.51	1.50	4.00
Cloud Cover	9.97	0.15	9.00	10.00
Visibility	13.63	2.57	8.00	15.00
Precipitation	0.022	0.15	0.00	1.00
Wind Speed	22.31	7.06	8.00	30.00
Wave Height	1.52	0.24	1.30	2.10
White Caps	0.95	0.56	0.00	2.00

Detections: 16 Opportunities: 44

POD Model:

Significant Variables	Coefficients
Constant	11.679160
CPA/Lateral Range	-1.562118
Wave Height	-5.010730

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Wave Height	2.1 nmi	1.7 nmi	1.3 nmi
Sweep Width	1.8 nmi	4.1 nmi	6.6 nmi

4.5.4 CCGS Alert – Bridge – NVGs - 4- and 6-Person Life Raft Canopy Lights

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.08	2.69	0.01	9.95
SRU Roll	3.23	1.96	0.00	10.00
Cloud Cover	7.21	4.05	0.00	10.00
Visibility	12.00	4.38	1.50	15.00
Precipitation	0.16	0.37	0.00	1.00
Wind Speed	18.42	7.45	2.00	35.00
Wave Height	1.81	0.50	1.00	3.00
White Caps	1.07	0.63	0.00	2.00

Detections: 61 Opportunities: 184

POD Model:

Significant Variables	Coefficients
Constant	4.288064
CPA/Lateral Range	-1.070916
Wind Speed	-0.095657

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
Wind Speed	30 kn	20 kn	10 kn
Sweep Width	3.1 nmi	4.6 nmi	6.3 nmi

4.5.5 CCGS Alert - Bridge - NVGs - 4- and 6-Person Life Rafts with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.57	0.35	0.00	1.30
Target Type	0.36	0.00	0.00	1.00
Cloud Cover	5.08	3.84	1.00	10.00
Visibility	12.52	4.73	2.50	15.00
Wind Speed	18.97	7.14	3.00	34.00
Wave Height	1.44	0.37	0.90	2.20
White Caps	1.08	0.64	0.00	2.00
Relative Swell Direction	1.19	0.62	0.00	2.00
Relative Humidity	67.75	14.63	48.00	94.00
Air Temperature	6.74	2.50	3.80	12.00
Moon Visibility	0.22	0.42	0.00	1.00
Moon Relative Azimut	0.91	0.60	0.00	2.00
Moon Elevation	41.66	20.50	7.00	70.00
Operator Time on Task	0.05	0.23	0.00	1.00

Detections: 10 Opportunities: 36

POD Model:

Significant Variables	Coefficients
Constant	2.231861
CPA/Lateral Range	-7.407328

Sample Sweep Width Calculations

For average conditions:	Sweep Width = .63 nmi

4.5.6 CCRS Convair 580 - C/X SAR - 4- and 6-Person Life Rafts with Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	5.03	2.45	0.70	9.50
Target Type	0.30	0.00	0.00	1.00
Target Radar Enhancement	0.59	0.00	0.00	1.00
Visibility	10.74	4.33	5.00	15.00
Wind Speed	23.78	4.87	20.00	30.00
Wave Height	1.52	0.60	1.00	2.30
White Caps	1.37	0.48	1.00	2.00

Detections: 23 Opportunities: 82

POD Model:

Significant Variables	Coefficients
Constant	0.258473
CPA/Lateral Range	-0.255346

Sample Sweep Width Calculations

For average conditions:	Sweep Width = 3.2 nmi (radar looks only one side)

4.5.7 USCGC Vigorous – Bridge - Daylight Visual - 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.27	2.73	0.01	9.96
Target Type	0.45	0.00	0.00	1.00
SRU Roll	5.10	4.07	0.00	16.00
Cloud Cover	8.66	1.88	3.00	10.00
Visibility	8.45	2.51	0.50	10.00
Precipitation	0.09	0.28	0.00	1.00
Wind Speed	19.53	7.75	0.00	37.00
Wave Height	1.79	0.87	0.50	4.20
White Caps	1.02	0.75	0.00	2.00

Detections: 130 Opportunities: 375

POD Model:

Significant Variables	Coefficients
Constant	2.561199
CPA/Lateral Range	-1.404737
SRU Roll	-0.136251
Visibility	0.340695
White Caps	-1.115225

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
SRU Roll Visibility White Caps	10 degrees 6 nmi Many	5 degrees 8 nmi Some	0 degrees 10 nmi None
Sweep Width	1.9 nmi	5.0 nmi	8.5 nmi

4.5.8 USCGC Vigorous – Flying Bridge - Daylight Visual - 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.32	2.73	0.01	9.96
Target Type	0.45	0.00	0.00	1.00
SRU Roll	5.12	4.12	0.00	16.00
Cloud Cover	8.81	1.65	3.00	10.00
Visibility	8.40	2.56	0.50	10.00
Precipitation	0.09	0.29	0.00	1.00
Wind Speed	19.43	7.90	0.00	37.00
Wave Height	1.78	0.89	0.30	4.20
White Caps	0.99	0.74	0.00	2.00

Detections: 129 Opportunities: 365

POD Model:

Significant Variables	Coefficients
Constant	4.700015
CPA/Lateral Range	-1.183577
SRU Roll	-0.141109
Visibility	0.240831
Wind Speed	-0.090941

Wave Height	-0.615609

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
SRU Roll Visibility Wind Speed Wave Height	10 degrees 6 nmi 25 kn 2.0 m	6 degrees 8 nmi 20 kn 1.5 m	2 degrees 10 nmi 15 kn 1.0 m
Sweep Width	2.5 nmi	5.2 nmi	nmi

4.5.9 USCGC Vigorous – Bridge – NVGs - 4- and 6-Person Life Raft Canopy Lights

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.37	2.83	0.25	9.98
SRU Roll	4.97	2.59	0.00	15.00
Cloud Cover	8.96	1.95	2.00	10.00
Visibility	8.51	2.01	3.00	10.00
Precipitation	0.33	0.47	0.00	1.00
Wind Speed	14.57	6.74	5.00	32.00
Wave Height	1.82	0.54	1.00	2.60
White Caps	0.68	0.60	0.00	2.00

Detections: 51 Opportunities: 118

POD Model:

Significant Variables	Coefficients
Constant	4.538169
CPA/Lateral Range	-1.098380
White Caps	-0.882754

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
White Caps	Many	Some	None
Sweep Width	5.2 nmi	6.7 nmi	8.3 nmi

4.5.10 USCGC Vigorous – Flying Bridge – NVGs - 4- and 6-Person Life Raft Canopy Lights

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.46	2.87	0.25	9.98
SRU Roll	4.91	2.66	0.00	15.00
Cloud Cover	8.89	2.00	2.00	10.00
Visibility	8.82	1.70	4.00	10.00
Precipitation	0.28	0.45	0.00	1.00
Wind Speed	13.50	5.60	5.00	26.00
Wave Height	1.77	0.52	1.00	2.40
White Caps	0.59	0.51	0.00	2.00

Detections: 43 Opportunities: 110

POD Model:

Significant Variables	Coefficients
Constant	4.787849
CPA/Lateral Range	-1.141050
White Caps	-1.688228

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 3
White Caps	Many	Some	None
Sweep Width	2.9 nmi	5.5 nmi	8.4 nmi

4.5.11 USCGC Vigorous – Bridge – NVGs - 4- and 6-Person Life Rafts with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.97	0.90	0.00	3.50
Target Type	0.38	0.00	0.00	1.00
SRU Pitch	3.36	2.73	1.00	14.00
SRU Roll	3.90	2.98	2.00	15.00
Cloud Cover	5.45	3.98	0.00	10.00
Visibility	9.30	1.80	4.00	12.00
Wind Speed	15.38	6.90	4.00	28.00
Wave Height	1.38	0.32	0.90	2.10
White Caps	0.47	0.57	0.00	2.00
Relative Swell Direction	0.90	0.67	0.00	2.00

Relative Humidity	71.09	11.09	56.00	93.00
Air Temperature	6.28	2.41	3.90	12.80
Moon Visibility	0.56	0.50	0.00	1.00
Moon Relative Azimut	0.96	0.57	0.00	2.00
Moon Elevation	52.12	16.28	11.00	71.00
Operator Time on Task	1.25	1.14	0.00	4.00

Detections: 21 Opportunities: 55

POD Model:

Significant Variables	Coefficients
Constant	-0.840706
CPA/Lateral Range	-0.943568
Moon Visibility	1.199969

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2
Moon Visibility	No	Yes
Sweep Width	.8 nmi	1.9 nmi

4.5.12 USCGC Vigorous – Flying Bridge – NVGs - 4- and 6-Person Life Rafts with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.67	0.37	0.20	1.70
Target Type	0.31	0.00	0.00	1.00
SRU Pitch	3.44	3.11	1.00	14.00
SRU Roll	4.00	3.28	2.00	15.00
Cloud Cover	5.92	3.89	0.00	10.00
Visibility	9.26	1.88	4.00	12.00
Wind Speed	14.71	7.32	4.00	28.00
Wave Height	1.38	0.34	0.90	2.10
White Caps	0.42	0.50	0.00	1.00
Relative Swell Direc	0.921	0.63	0.00	2.00
Relative Humidity	70.89	12.58	56.00	93.00
Air Temperature	6.67	2.16	4.40	10.60
Moon Visibility	0.52	0.50	0.00	1.00
Moon Relative Azimut	0.81	0.60	0.00	2.00
Moon Elevation	47.81	16.35	11.00	67.00

Operator Time on Task	1.39	1.24	0.00	4.00

Detections: 12 Opportunities: 38

POD Model:

Significant Variables	Coefficients
Constant	4.448131
CPA/Lateral Range	-3.754455
Cloud Cover	-0.225619
Wind Speed	-0.108212

Sample Sweep Width Calculations

Variable	Value Set 1	Value Set 2	Value Set 2
Cloud Cover Wind Speed	8/10 20 kn	6/10 15 kn	4/10 10 kn
Sweep Width	.5 nmi	.9 nmi	1.4 nmi

4.5.13 USCG UTBs – NVGs - 5.5 and 6.4 m Boats

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.50	0.31	0.00	1.00
SRU Speed	16.31	3.14	8.00	23.00
Cloud Cover	2.67	3.62	0.00	10.00
Visibility	11.06	4.56	2.50	15.00
Wind Speed	9.53	2.76	5.00	15.00
Wave Height	0.64	0.10	0.50	0.90
White Caps	0.43	0.50	0.00	1.00
Relative Swell Direction	1.01	0.65	0.00	2.00
Relative Humidity	75.92	18.08	51.00	95.00
Air Temperature	17.94	1.46	16.40	21.30
Water Temperature	18.78	0.51	17.80	21.70
Artificial Light	0.71	0.45	0.00	1.00
Moon Visibility	0.73	0.44	0.00	1.00
Moon Relative Azimut	0.29	0.49	0.00	2.00
Moon Elevation	19.76	22.69	-32.00	45.00
Operator Time on Task	1.68	1.52	0.00	4.00

Detections: 10 Opportunities: 64

POD Model:

Significant Variables	Coefficients
Constant	0.559013
CPA/Lateral Range	-6.950977

Sample Sweep Width Calculations

For average conditions:	Sweep Width = .29 nmi

4.5.14 USCG UTBs – NVGs - PIWs with Red Safety Lights (RSL)

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.51	0.30	0.10	1.00
SRU Speed	13.04	3.20	8.00	15.00
Cloud Cover	7.12	2.80	3.00	9.00
Precipitation	0.24	0.83	0.00	3.00
Wind Speed	9.08	3.86	5.00	15.00
Wave Height	0.76	0.16	0.60	1.10
White Caps	0.28	0.45	0.00	1.00
Relative Swell Direction	0.84	0.55	0.00	2.00
Relative Humidity	76.64	1.89	74.00	78.00
Air Temperature	24.30	1.13	23.30	26.00
Water Temperature	23.59	0.16	23.50	24.00
Operator Time on Task	1.84	1.77	0.00	5.00

Detections: 2 Opportunities: 25

POD Model:

No model solution.

4.5.15 USCG UTBs – NVG - 4- and 6-Person Life Rafts with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.51	0.28	0.00	1.00
SRU Speed	15.64	3.15	10.00	23.00
Cloud Cover	2.59	3.34	0.00	10.00
Visibility	11.38	4.59	0.50	16.00
Wind Speed	9.47	2.51	5.00	17.00
Wave Height	0.65	0.20	0.50	1.30
White Caps	0.23	0.47	0.00	2.00

Relative Swell Direction	0.99	0.60	0.00	2.00
Relative Humidity	73.15	19.21	50.00	95.00
Air Temperature	17.64	2.26	15.20	23.90
Water Temperature	19.00	0.84	17.50	22.10
Artificial Light	0.81	0.39	0.00	1.00
Moon Visibility	0.35	0.47	0.00	1.00
Moon Relative Azimut	0.67	0.52	0.00	2.00
Moon Elevation	-4.66	23.07	-63.00	38.00
Moon Phase	2.14	0.73	1.00	4.00

Detections: 9 Opportunities: 134

POD Model:

Significant Variables	Coefficients
Constant	0.534963
CPA/Lateral Range	-11.980574

Sample Sweep Width Calculations

For average conditions:	Sweep Width = .17 nmi.

4.5.16 USCG UTBs – NVGs - 4- and 6-Person Life Rafts without Reflective Tape in Moonlight Conditions

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.47	0.33	0.00	1.00
SRU Speed	14.96	1.45	12.00	18.00
Cloud Cover	0.62	1.07	0.00	3.00
Wind Speed	11.74	3.07	7.00	16.00
Wave Height	0.76	0.16	0.50	1.20
White Caps	0.92	0.54	0.00	2.00
Relative Swell Direction	1.18	0.68	0.00	2.00
Relative Humidity	60.29	7.66	51.00	72.00
Air Temperature	18.44	2.50	16.50	23.80
Water Temperature	19.35	1.59	17.80	22.00
Moon Relative Azimut	0.37	0.74	0.00	2.00
Moon Elevation	34.85	8.01	16.00	52.00
Moon Phase	3.81	0.39	3.00	4.00
Operator Time on Task	1.66	1.77	0.00	6.00

Detections: 10 Opportunities: 27

POD Model:

Significant Variables	Coefficients
Constant	4.040228
CPA/Lateral Range	-14.130795

Sample Sweep Width Calculations

For average conditions:	Sweep Width = .57 nmi.

4.6 Analysis of Individual Data Sets for 1994

4.6.1 CCGC Bickerton - Daylight Visual - 4- and 6-Person Orange Drifting Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	2.85	1.66	0.20	5.85
Target Type	0.22	0.00	0.00	1.00
SRU Speed	14.09	1.00	12.00	16.00
Cloud Cover	5.68	3.73	1.00	10.00
Visibility	5.72	0.58	4.50	6.00
Wind Speed	10.88	6.25	0.00	25.00
Wave Height	1.46	0.23	1.00	2.00
White Caps	0.35	0.56	0.00	2.00
Air Temperature	12.46	1.22	10.50	15.00

Detections: 28 Opportunities: 70

POD Model:

Significant Variables	Coefficients
Constant	4.100333
CPA/Lateral Range	-1.813013

Sample Sweep Width Calculations

For average conditions:	Sweep Width = 4.5 nmi

4.7 Analysis of Individual Data Sets for 1995

4.7.1 M.V. Nain Banker - Bridge - Daylight Visual - 4-, 6- and 20-Person Drifting Orange Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.09	2.06	0.17	5.58
SRU Speed	7.39	1.35	5.20	10.00
SRU Pitch	3.95	1.03	3.00	5.50
SRU Roll	9.25	5.08	6.00	20.00
Cloud Cover	8.91	1.88	5.00	10.00
Wind Speed	18.75	3.64	13.00	22.00
Wave Height	4.25	0.34	3.60	4.70
White Caps	1.75	0.45	1.00	2.00
Relative Swell Direction	1.66	0.65	0.00	2.00
Air Temperature	-2.42	1.39	-4.00	-1.30
Water Temperature	4.70	0.25	4.50	5.00
Sun Visibility	0.16	0.38	0.00	1.00

Detections: 4 Opportunities: 12

No model solution.

4.7.2 M.V. Nain Banker - Bridge - Daylight Visual - Drifting PIWs with Orange Floater Suits

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.20	0.78	0.16	3.54
SRU Speed	6.10	0.62	4.50	7.00
SRU Pitch	1.97	0.76	1.00	4.00
SRU Roll	4.27	1.87	2.00	10.00
Cloud Cover	6.17	3.45	1.00	10.00
Precipitation	0.21	0.41	0.00	1.00
Wind Speed	10.59	5.15	4.00	19.00
Wave Height	1.50	0.25	1.20	2.20
White Caps	0.94	0.72	0.00	2.00
Relative Swell Direction	1.19	0.62	0.00	2.00
Air Temperature	-0.79	2.01	-4.50	2.60
Water Temperature	4.95	0.25	4.60	5.60
Sun Visibility	0.44	0.50	0.00	1.00

Detections: 9 Opportunities: 52

POD Model:

Significant Variables	Coefficients
Constant	0.621446
CPA/Lateral Range	-2.544065

Sample Sweep Width Calculations

For average conditions: Sweep width = .83 nmi.

4.7.3 CCGS Sir Humphrey Gilbert - 4016 Sperry Radar – Drifting 6 m Boats with Hi-Flyer Radar Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	5.00	2.63	0.28	10.03
SRU Speed	6.99	1.32	4.30	8.50
Visibility	5.70	2.50	3.50	10.00
Precipitation	0.33	0.48	0.00	1.00
Wind Speed	15.83	1.16	14.00	17.00
Wave Height	1.17	0.18	1.00	1.50
Relative Swell Direction	0.91	0.65	0.00	2.00
Air Temperature	6.24	0.61	5.50	7.40

Detections: 5 Opportunities: 24

POD Model:

Significant Variables	Coefficients
Constant	1.979428
CPA/Lateral Range	-0.883390

Sample Sweep Width Calculations

For average conditions: Sweep width = 4.8 nmi.

4.7.4 CCGS Sir Humphrey Gilbert - 4016 Sperry Radar – Drifting PIWs

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.53	0.96	0.01	3.58
Radar Range Scale	2.23	0.75	1.50	3.00
SRU Speed	6.63	2.16	4.20	12.50

Cloud Cover	4.69	3.99	1.00	10.00
Visibility	8.24	3.99	0.38	11.00
Precipitation	0.28	0.45	0.00	1.00
Wind Speed	16.96	5.02	4.00	23.00
Wave Height	1.16	0.27	0.80	1.50
White Caps	0.80	0.39	0.00	1.00
Air Temperature	-1.09	2.46	-5.40	2.70
Water Temperature	4.82	0.43	4.10	5.60

Detections: 2 Opportunities: 63

POD Model:

Significant Variables	Coefficients
Constant	-2.038239
CPA/Lateral Range	-1.257294 (73 % confidence level)

Sample Sweep Width Calculations

For average conditions: Sweep Width = .19 nmi.

4.7.5 CCGS Sir Humphrey Gilbert - TITAN Processing - 4-, 6- and 20-Person Drifting Life Rafts with Reflectors

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	5.07	3.40	0.84	10.84
SRU Speed	5.87	1.19	4.30	7.10
Visibility	9.63	1.56	8.00	11.00
Precipitation	0.45	0.52	0.00	1.00
Wind Speed	20.18	2.08	18.00	22.00
Wave Height	4.45	0.25	4.20	4.70
Relative Swell Direction	0.90	1.04	0.00	2.00
Air Temperature	-1.58	0.40	-2.00	-1.20
Water Temperature	5.90	0.03	5.90	6.00

Detections: 2 Opportunities: 11

POD Model:

No model solution.

4.7.6 CCGS Sir Humphrey Gilbert - TITAN Processing - Drifting PIWs

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	1.08	0.90	0.12	3.54
Radar Range Scale	2.28	0.81	0.75	3.00
SRU Speed	6.34	0.67	4.30	7.30
Cloud Cover	8.54	2.18	4.00	10.00
Wind Speed	13.58	4.44	4.00	20.00
Wave Height	1.00	0.44	0.50	1.50
White Caps	0.37	0.49	0.00	1.00
Air Temperature	-1.50	1.32	-3.80	1.00
Water Temperature	4.52	0.09	4.40	4.60

Detections: 7 Opportunities: 24

POD Model:

Significant Variables	Coefficients
Constant	0.494825
CPA/Lateral Range	-1.654203

Sample Sweep Width Calculations

For average conditions:	Sweep Width = 1.2 nmi.

4.8 Analysis of Combined Data Sets for Common SAR Targets

4.8.1 All CCGS Alert - Daylight Visual - 4- and 6-Person Drifting Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.00	2.74	0.04	9.98
Target Type	0.42	0.00	0.00	1.00
Sensor Elevation	10.96	0.75	10.70	13.10
Cloud Cover	8.91	2.11	3.00	10.00
Visibility	10.63	4.38	1.50	15.00
Precipitation	0.03	0.19	0.00	1.00
Wind Speed	21.29	7.70	4.00	34.00
Wave Height	1.71	0.66	0.70	2.70
White Caps	1.30	0.78	0.00	2.00

Detections: 146 Opportunities: 401

POD Model:

Significant Variables:	Coefficients:
Constant	6.35
CPA/Lateral Range	-1.819668
Target Type	0.770897
Wind Speed	-0.098094

Sample sweep width calculations:

Variable	Value Set 1	Value Set 2	Value Set 2
Target Type Wind Speed	4-person raft 30 kn	4- and 6-person rafts 20 kn	6-person raft 10 kn
Sweep Width	3.8 nmi	5.3 nmi	6.8 nmi

4.8.2 All USCGC Vigorous - Daylight Visual - 4- and 6-Person Orange & Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.29	2.73	0.01	9.96
Target Type	0.45	0.00	0.00	1.00
Sensor Elevation	13.98	1.20	12.80	15.20
SRU Roll	5.11	4.09	0.00	16.00
Cloud Cover	8.73	1.77	3.00	10.00
Wind Speed	19.48	7.82	0.00	37.00
Wave Height	1.78	0.88	0.30	4.20
White Caps	1.00	0.75	0.00	2.00

Detections: 259 Opportunities: 740

POD Model:

Significant Variables:	Coefficients:
Constant	6.352536
CPA/Lateral Range	-1.221355
Wind Speed	-0.075798
Wave Height	-0.892955

Sample sweep width calculations:

Variable	Value Set 1	Value Set 2	Value Set 2
Wind Speed Wave Height	30 kn 2.5 m	20 kn 1.5 m	10 kn 0.5 m
Sweep Width	3.3 nmi	5.8 nmi	8.4 nmi

4.8.3 All CCGS Sir William Alexander – Daylight Visual – 4- and 6-Person Orange and Yellow Life Rafts

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	3.28	1.96	0.02	9.61
Target Type	0.35	0.00	0.00	1.00
Sensor Elevation	12.85	0.66	12.70	15.70
Cloud Cover	6.55	3.29	0.00	10.00
Visibility	13.94	2.21	5.00	15.00
Precipitation	0.08	0.27	0.00	1.00
Wind Speed	20.21	8.10	2.00	43.00
Wave Height	1.57	0.41	0.60	2.50
White Caps	1.08	0.71	0.00	2.00

Detections: 189 Opportunities: 617

POD Model:

Significant Variables:	Coefficients:
Constant	4.243053
CPA/Lateral Range	-1.177815
Target Type	0.853495
Cloud Cover	-0.070440
Wave Height	-1.184192

Sample sweep width calculations

Variable	Value Set 1	Value Set 2	Value Set 2
Target Type Wind Speed Wave Height	4-person raft 10/10 2.0 m	4- and 6-person rafts 7/10 1.6 m	6-person raft 4/10 1.0 m
Sweep Width	2.4 nmi	4.0 nmi	6.2 nmi

4.8.4 All USCGC Vigorous - NVGs - 4- and 6-Person Life Raft Canopy Lights

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	4.41	2.84	0.25	9.98
Sensor Elevation	13.95	1.20	12.80	15.20
SRU Roll	4.94	2.62	0.00	15.00
Cloud Cover	8.92	1.97	2.00	10.00
Visibility	8.66	1.87	3.00	10.00
Precipitation	0.30	0.46	0.00	1.00
Wind Speed	14.06	6.23	5.00	32.00
Wave Height	1.80	0.53	1.00	2.60
White Caps	0.64	0.56	0.00	2.00

Detections: 94 Opportunities: 228

POD Model:

Significant Variables:	Coefficients:
Constant	4.509251
CPA/Lateral Range	-1.097099
White Caps	-1.122491

Sample sweep width calculations:

Variable	Value Set 1	Value Set 2	Value Set 2
White Caps	Many	Some	None
Sweep Width	4.3 nmi	6.2 nmi	8.4 nmi

4.8.5 All USCGC Vigorous - NVGs - 4- and 6-Person Life Rafts with Reflective Tape

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.65	0.37	0.00	1.70
Target Type	0.34	0.00	0.00	1.00
Sensor Elevation	13.87	1.20	12.80	15.20
Cloud Cover	6.14	3.73	0.00	10.00
Visibility	9.22	1.89	4.00	12.00
Wind Speed	15.12	7.36	4.00	28.00
Wave Height	1.40	0.34	0.90	2.10
White Caps	0.43	0.54	0.00	2.00
Moon Visibility	0.50	0.50	0.00	1.00
Operator Time on Task	1.35	1.21	0.00	4.00

Detections: 31 Opportunities: 85

POD Model:

Significant Variables:	Coefficients:
Constant	3.774752
CPA/Lateral Range	-3.246759
Cloud Cover	-0.193859
Wind Speed	-0.076559

Sample sweep width calculations:

Variable	Value Set 1	Value Set 2	Value Set 2
Cloud Cover Wind Speed	10/10 20 kn	6/10 15 kn	2/10 10 kn
Sweep Width	0.5 nmi	1.0 nmi	1.7 nmi

4.8.6 All USCG UTBs – NVGs – 5.5 and 6.4 m Boats

Input Data:	Average	Std. Dev.	Minimum	Maximum
CPA/Lateral Range	0.55	0.39	0.00	2.00
Target Type	0.43	0.00	0.00	1.00
SRU Speed	15.73	2.83	8.00	23.00
Cloud Cover	3.40	3.86	0.00	10.00
Visibility	10.46	4.19	1.50	15.00
Precipitation	0.01	0.07	0.00	1.00

Wind Speed	9.15	4.13	2.00	20.00
Wave Height	0.75	0.21	0.40	1.30
White Caps	0.76	0.74	0.00	2.00
Moon Visibility	0.43	0.49	0.00	1.00
Operator Time on Task	1.90	1.46	0.00	6.00

Detections: 26 Opportunities: 196

POD Model:

Significant Variables:	Coefficients:
Constant	2.707300
CPA/Lateral Range	-10.930473
Target Type	1.664142
Wave Height	-3.196419

Sample sweep width calculations:

Variable	Value Set 1	Value Set 2	Value Set 2
Target Type Wave Height	5.5 m boat 1.2 m	5.5 & 6.4 m boats 0.8 m	6.4 m boat 0.4 m
Sweep Width	0.1 nmi	0.2 nmi	0.6

4.9 POD Curves for Combined Data Sets

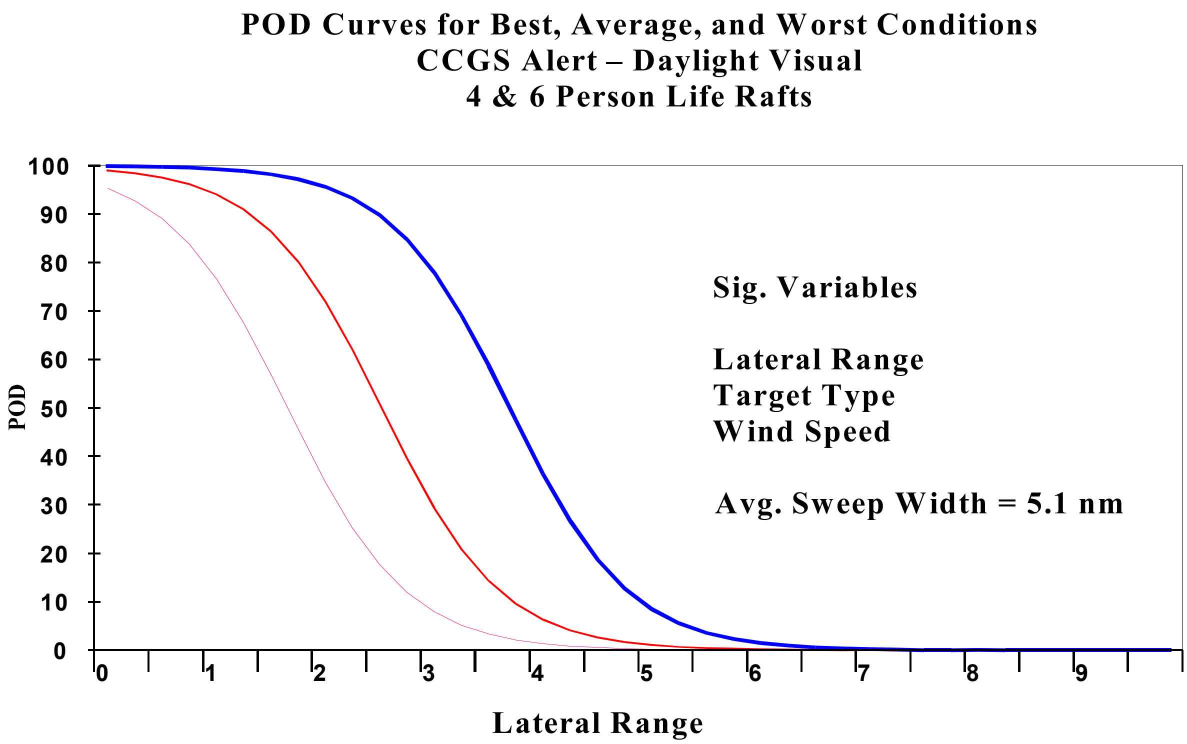

Figure 4.1: POD Curves CCGS Alert – Daylight Visual – 4- and 6-Person Life Rafts

Variable	Best	Average	Worst
Target Type Wind Speed	6-person raft 4 kn	4- and 6-person rafts 21 kn	4-person raft 34 kn
Sweep Width	7.4 nmi	5.1 nmi	3.4 nmi

Figure 4.1 presents the POD curves for the combined data set of all daylight visual searches conducted from the CCGS Alert for 4- and 6-person orange and yellow life rafts. The combined data consists of 401 detection opportunities. The POD curves can be considered reliable for the conditions contained within the data set.

POD Curves for Best, Average, and Worst Conditions
USCGC Vigorous – Daylight Visual
4 & 6 Person Life Rafts

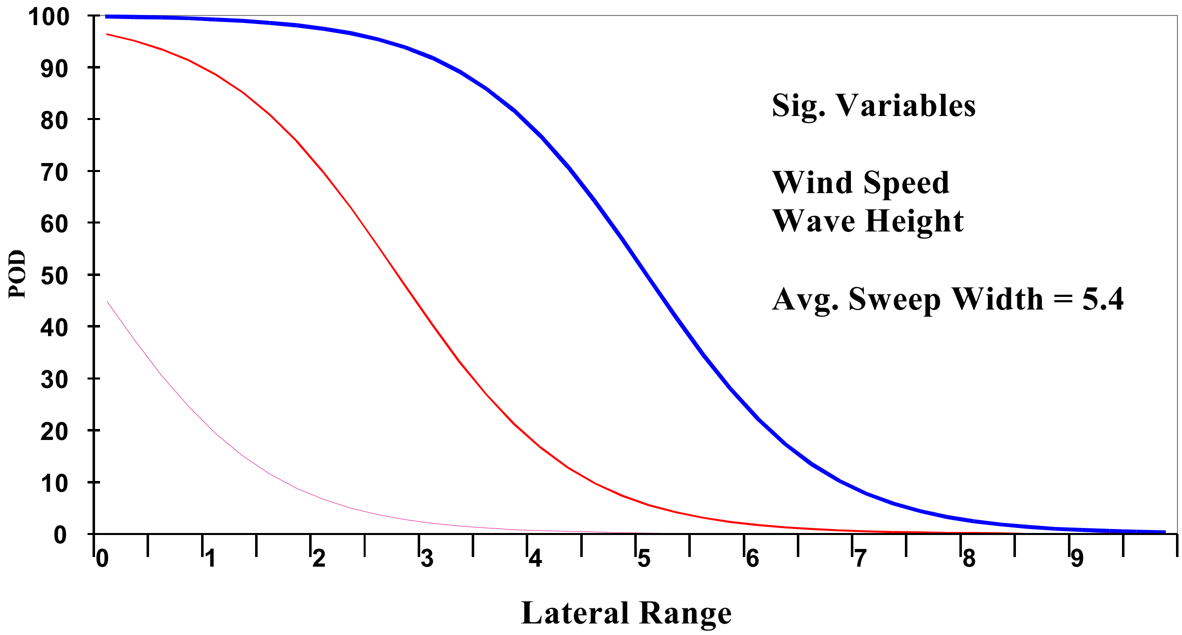

Figure 4.2: POD Curves USCGC Vigorous – Daylight Visual – 4- and 6-Person Life Rafts

Variable	Best	Average	Worst
Wind Speed Wave Height	Calm 0.3 m	19 kn 1.8 m	37 kn 4.2 m
Sweep Width	10.0 nmi	5.4 nmi	1.0 nmi

Figure 4.2 presents the POD curves for the combined data set of all daylight visual searches conducted from the USCGC Vigorous for 4- and 6-person orange and yellow life rafts. The combined data consists of 740 detection opportunities. The POD curves can be considered reliable for the conditions contained within the data set.

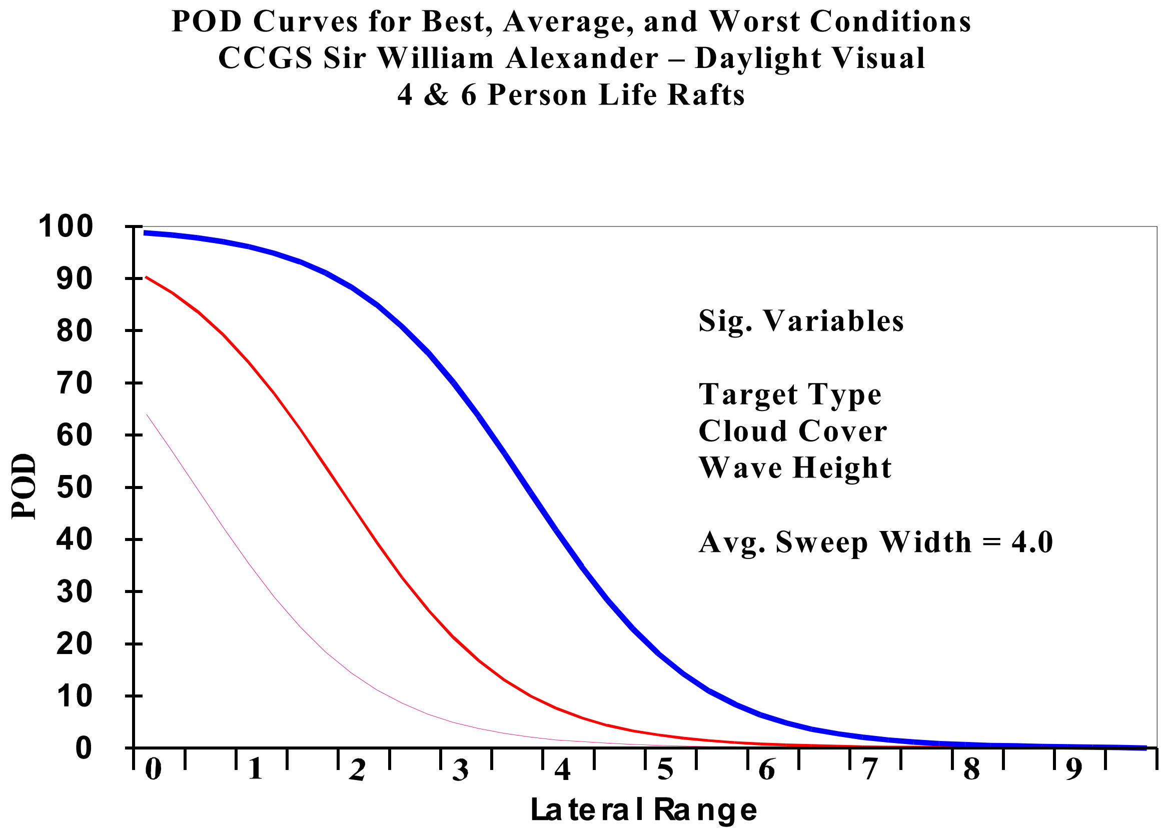

Figure 4.3: POD Curves CCGS Sir William Alexander – Daylight Visual – 4- and 6-Person Life Rafts

Variable	Best	Average	Worst
Target Type Cloud Cover Wave Height	6-person raft Clear 0.6 m	4- and 6-person rafts 7/10 1.6 m	4-person raft 10/10 2.5 m
Sweep Width	7.5	4.0	1.7

Figure 4.3 presents the POD curves for the combined data set of all daylight visual searches conducted from the CCGS Sir William Alexander for 4- and 6-person orange and yellow life rafts. The combined data consists of 617 detection opportunities. The POD curves can be considered reliable for the conditions contained within the data set.

POD Curves for Best, Average, and Worst Conditions
USCGC Vigorous – NVG - 4 & 6 Person Life Raft Canopy Lights

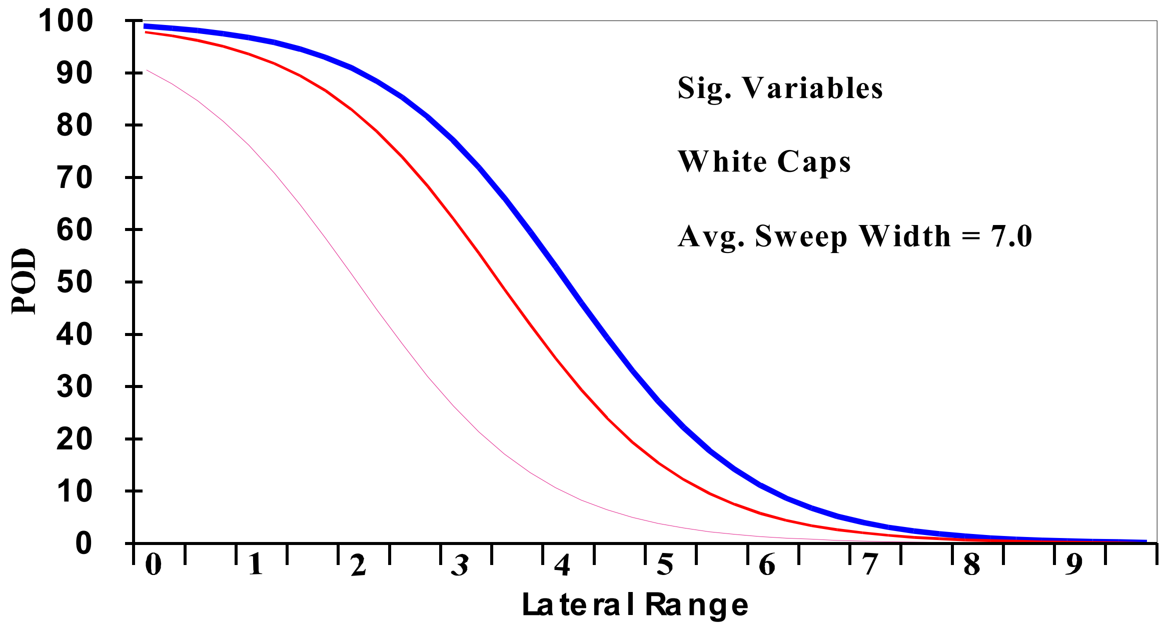

Figure 4.4: POD Curves USCGC Vigorous – NVGs – 4- and 6-Person Life Rafts

Variable	Best	Average	Worst
White Caps	None	None – Some	Many
Sweep Width	8.2 nmi	7.0 nmi	4.3 nmi

Figure 4.4 presents the POD curves for the combined data set of all NVG searches conducted from the USCGC Vigorous for 4- and 6-person life raft canopy lights. The combined data consists of 228 detection opportunities. The POD curves can be considered reliable for the conditions contained within the data set.

POD Curves for Best, Average, and Worst Conditions
USCGC Vigorous – NVG - 4 & 6 Person Life Rafts with Reflective Tape

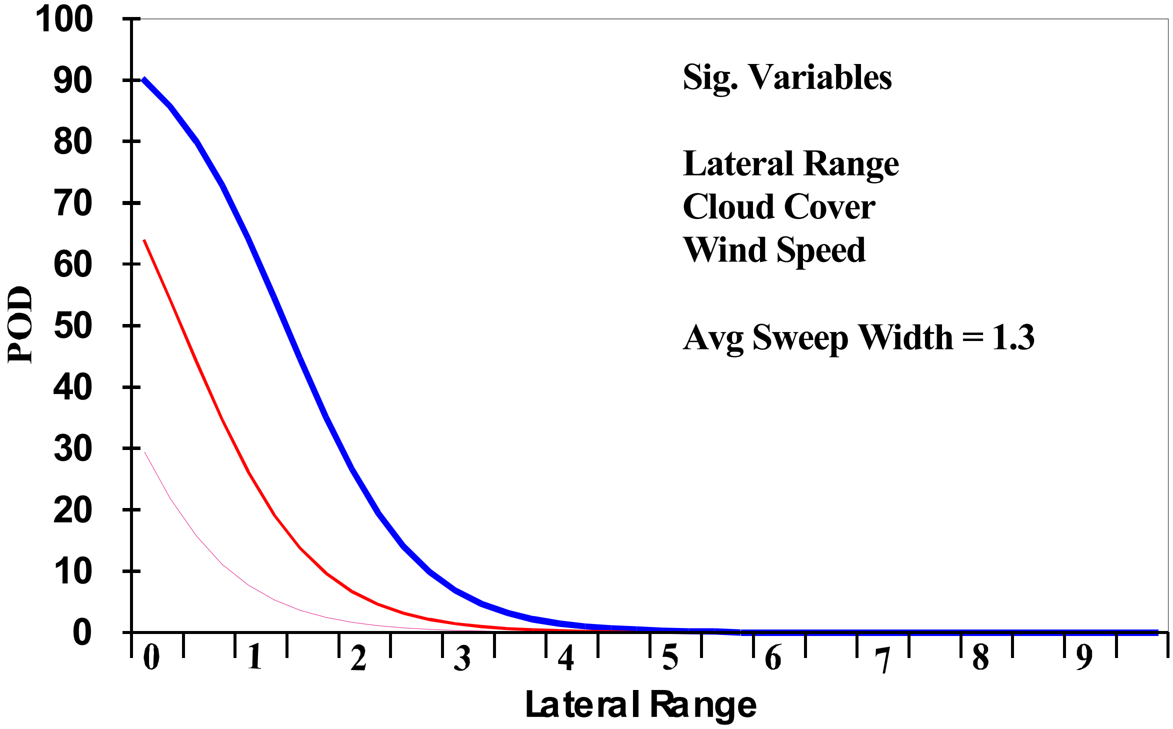

Figure 4.5: POD Curves USCGC Vigorous – NVGs – 4- and 6-Person Life Rafts with Reflective Tape

Variable	Best	Average	Worst
Cloud Cover Wind Speed	Clear 4 kn	6/10 15 kn	10/10 28 kn
Sweep Width	2.9 nmi	1.3 nmi	0.4 nmi

Figure 4.5 presents the POD curves for the combined data set of all NVG searches conducted from the USCGC Vigorous for 4- and 6-person life rafts with reflective tape. The combined data consists of 88 detection opportunities. The POD curves should be considered preliminary. Moon visibility was not found to be significant in this data set; however, the best sweep widths can expected to be obtained in moonlit conditions.

POD Curves for Best, Average, and Worst Conditions
USCG UTBs – NVG - 5.5 & 6.4 m Boats

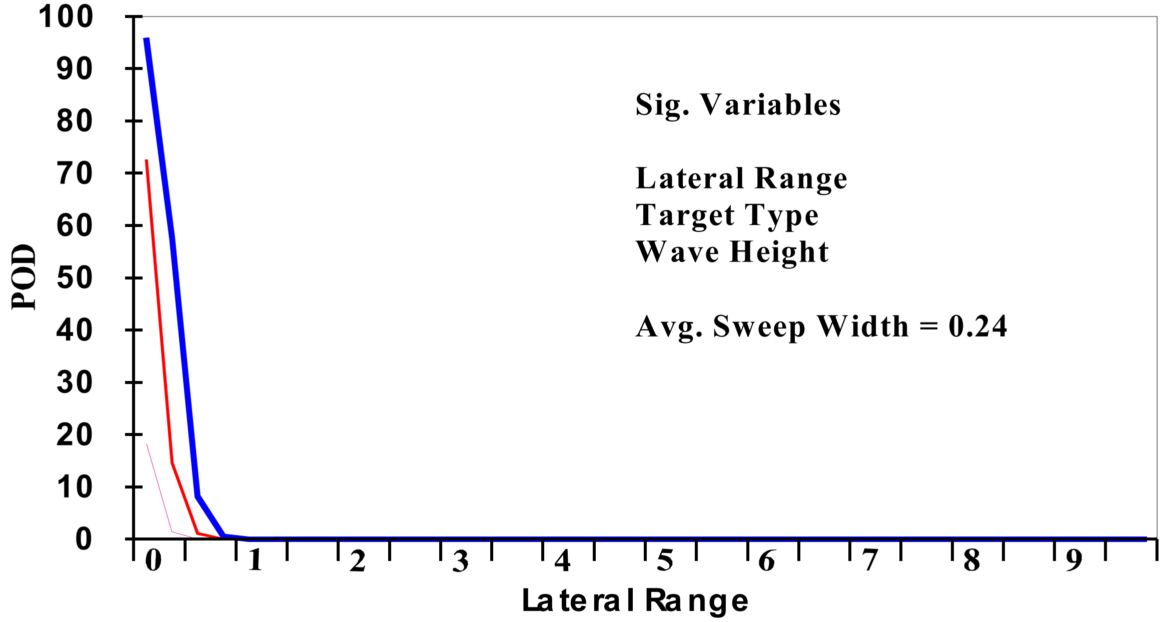

Figure 4.6: POD Curves USCG UTBs – NVGs – 5.5 and 6.4 m Boats

Variable	Best	Average	Worst
Target Type Wave Height	6.4 m boat 0.4 m	5.5 & 6.4 m boats 0.8 m	5.5 m boat 1.3 m
Sweep Width	0.57 nmi	0.24 nmi	0.04 nmi

Figure 4.6 presents the POD curve for the combined data set of all NVG searches conducted from the USCG UTBs for 5.5 m and 6.4 m boats. The combined data consists of 194 detection opportunities. Moon visibility was not found to be significant in this data set; however, the best sweep widths can expected to be obtained in moonlit conditions.

4.10 Review of POD Models for 1995 Data Sets

4.10.1 M.V. Nain Banker – Bridge - Daylight Visual – Drifting PIWs with Orange Floater Suits

Detections: 9 Opportunities: 52

POD Model:

Significant Variables	Coefficients
Constant	0.621446
CPA/Lateral Range	-2.544065

Sample Sweep Width Calculations

For average conditions: Sweep width = .83 nmi.

The results obtained from this data set appear reasonable but must be considered preliminary and should be used accordingly. The sweep width is only valid for the conditions contained within the data set. Average wind speed during the data collection was 11 kn and wave heights averaged 1.5 m. This data set appears to be the first daylight visual search for PIWs collected either in Canada or the US.

4.10.2 CCGS Sir Humphrey Gilbert - 4016 Sperry Radar - 6 m Boats with Hi-Flyer Radar Reflectors

Detections: 5 Opportunities: 24

POD Model:

Significant Variables	Coefficients
Constant	1.979428
CPA/Lateral Range	-0.883390

Sample Sweep Width Calculations

For average conditions: Sweep width = 4.8 nmi.

The results obtained from this data set appear reasonable and show good promise for the use of radar in the detection of small wooden boats equipped with radar reflectors exhibiting a cross section similar to a hi-flyer that was used in the 1995 trials. The results must be considered preliminary and should be used accordingly. The sweep width is only valid for the conditions contained within the data set. Average wind speed during the data collection was 16 kn and wave heights averaged 1.2 m.

4.10.3 CCGS Sir Humphrey Gilbert - 4016 Sperry Radar - PIWs

Detections: 2 Opportunities: 63

POD Model:

Significant Variables	Coefficients
Constant	-2.038239
CPA/Lateral Range	-1.257294

Sample Sweep Width Calculations

For average conditions: Sweep Width = .19 nmi.

The results obtained from this data set showed poor performance of the Sperry 4016 radar on board the CCGS Sir Humphrey Gilbert against PIWs. However, the results must be considered preliminary and are only valid for the conditions contained within the data set. Average wind speed was 17 kn and wave heights averaged 1.2 m.

4.10.4 CCGS Sir Humphrey Gilbert - TITAN Processing - PIWs

Detections: 7 Opportunities: 24

POD Model:

Significant Variables	Coefficients
Constant	0.494825
CPA/Lateral Range	-1.654203

Sample Sweep Width Calculations

For average conditions: Sweep Width = 1.2 nmi.

With TITAN processing applied to the radar data from the Sperry 4016 radar the resulting sweep width for PIWs was far better than that obtained by the Sperry 4016 standard processing. However, again the results must be considered preliminary and should be used accordingly and are valid only within the conditions contained within the data set The data set was collected in conditions with an average wind speed of 14 kn and wave heights of 1 m.

4.10.5 Other 1995 Data Sets

Other detection data sets were collected in 1995 and these included a data set for the TITAN processor against 4-,6- and 20-person life rafts equipped with radar reflectors. The data set consisted of only 11 opportunities of which 2 were detected. The data set was too small to yield a result.

A small data set was also collected on NVG performance from the Nain Banker against PIWs with reflective tape. The data set consisted of 24 detection opportunities of which none were detected.

4.11 Sweep Width Summary

Table 4.1 provides the sweep width values for the various platform/sensor/target data sets reviewed. Sweep width values are based on the average values of the significant variables. Where lateral range is the only significant variable the sweep width is based on average conditions contained in the data set. Where no model solution was found the sweep width was estimated. To provide an indication of environmental conditions contained within each data set, average winds and waves are provided under average conditions.

Table 4.1
Sweep Width Summary

Search Type	**Target**	**Platform (**detections/opportunities**)**	**Average Conditions** (wind in kn, waves in m)	**Sweep Width** (nmi)
Day Visual	**4-6-person rafts**	CCGS Jackman Bridge (32/76)	Wind = 12 , Waves = 1.1	3.4
		CCGS Sir William Alexander Bridge/Flying Bridge (189/617)	Wind = 20, Waves = 1.6	4.0
		CCGS Alert Bridge/Flying Bridge (146/401)	Wind = 21, Waves = 1.7	5.1
		CCGS Sir William Alexander Flying Bridge (13/32)	Wind = 23, Waves = 1.9	3.6
		USCGC Vigorous Bridge/Flying Bridge (259/740)	Wind = 19, Waves = 1.8	5.4
		CCGC Bickerton (28/70)	Wind = 11, Waves = 1.5	4.5
	PIWs with orange survival suits	M.V. Nain Banker (9/52)	Wind = 11, Waves = 1.5	0.8
	Hand-held orange smoke flares	USCG Work Patrol Boats (WPBs) (46/117)	Wind = 5, Waves = 0.5	5.6
		USCG Utility Boats (UTBs) (20/50)	Wind = 5, Waves = 0.5	3.4
Night Visual	**Raft canopy lights**	CCGS Alert Bridge (2/18)	Wind = 34, Waves = 3.1	0.7
	White strobes	USCG WPBs & UTBs (155/336)	Wind = 9, Waves = 0.8	2.0
	Hand-held red flares	USCG WPBs (165/211)	Wind = 7, Waves = 0.5	12.7
		USCG UTBs (188/278)	Wind = 6, Waves = 0.4	10.4

Table 4.1 Cont'd

Search Type	**Target**	**Platform** (detections/opportunities)	**Average Conditions** (wind in kn, waves in m)	**Sweep Width** (nmi)
NVGs	**PIWs with reflective tape**	USCG UTBs (14/239)	Wind = 9, Waves = 0.7	0.07
		M.V. Nain Banker (0/24)	Wind = 12, Waves = 1.8	-
	5.5 & 6.4 m boats	USCG UTBs (26/196)	Wind = 9, Waves = 0.8	0.2
	4-6-person rafts without reflective tape	USCG UTBs (17/190) No Moon*	Wind = 10, Waves = 0.8	0.2*
		USCG UTBs (10/27) Moonlight Conditions*	Wind = 12, Waves = 0.8	0.6*
	4-6-person rafts with reflective tape	Alert Bridge (10/36)	Wind = 19, Waves = 1.4	0.6
		USCGC Vigorous Bridge/Flying Bridge (31/85)	Wind = 15, Waves = 1.4	1.0
		USCG UTBs (9/134)	Wind = 9, Waves = 0.7	0.2
		M.V. Nain Banker (0/16)	Wind = 21, Waves= 4.7	-
	4-6-person rafts with canopy lights	CCGS Alert Bridge (61/184)	Wind = 18, Waves = 1.8	4.6
		USCGC Vigorous Bridge/Flying Bridge (94/228)	Wind = 14, Waves = 1.8	6.2
	PIWs with red safety lights	USCG UTBs (2/25)	Wind = 9, Waves = 0.8	-

Table 4.1 Cont'd

Search Type	**Target**	**Platform (**detections/opportunities**)**	**Average Conditions** (wind in kn, waves in m)	**Sweep Width** (nmi)
Sperry 127E Radar	**4-person rafts without reflectors**	CCGS Jackman (7/27)	Wind = 12, Waves = 0.9	0.8
	4-person rafts with reflectors	CCGS Jackman (12/45)	Wind = 14, Waves = 1.2	2.7
Sperry 4016 Radar	**6 m boats with hi-flyer reflectors**	CCGS Sir Humphrey Gilbert (5/24)	Wind = 16, Waves = 1.2	4.8
	PIWs	CCGS Sir Humphrey Gilbert (2/63)	Wind = 17, Waves = 1.2	0.2
TITAN Processing	**PIWs**	CCGS Sir Humphrey Gilbert (7/24)	Wind = 14, Waves = 1.0	1.2
	4-6-20 person rafts with reflectors	CCGS Sir Humphrey Gilbert (2/11)	Wind = 20, Waves = 4.5	-
APS-504(V) 5 Search Radar	**4-6-person rafts with reflectors**	King Air B200 (29/189) King Air B200 (29/128)	Wind = 23, Waves = 2.1 Wind = 15, Waves = 1.3	5.3 3.4
C/X SAR *(one way)	**4-6-person rafts with reflectors**	CCRS Convair 580 (23/82)	Wind = 24, Waves = 1.5	3.2*

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Data Management and Software Development

Much of the experimental search data collected by the CCG and USCG dating back to 1986 has been assembled under this project. The USCG data primarily consisted of processed data ready for input into POD modeling. In addition to POD modeling input data, many ancillary data sets were assembled with respect to CCG data.

Data base formats were designed for both field data collection and for model input data. The data base was designed following a review of formats used in past experiments.

All assembled data was transferred to Excel format and entered into the newly designed data base formats.

A major part of the project was the development of data management and analysis software tool. This tool came to be known as the SAR Data Analysis Software (SARDAS).

SARDAS was used to review all the POD data sets assembled and provide POD models for each of the data sets reviewed. For the most part model results were very similar to those results that were published from previous experiments.

Daylight Visual Searches

Based on the data assembled, daylight visual average sweep widths ranged from 3.4 nmi (CCGS Jackman) to 5.4 nmi (USCGC Vigorous). Vessel stability and height of eye have an obvious influence on detection performance..

There has been only one data set collected on daylight visual searching for PIWs with orange survival suits. This was carried out by the M.V. Nain Banker. Results showed a sweep width of 0.8 nmi based on average conditions. The data set should be considered preliminary.

Sweep width for daylight visual searches for hand-held orange smoke flares ranged from 3.4 nmi (UTBs) to 5.6 nmi (WPBs). Data was collected in very light conditions with an average wind speed of 5 kn and an average wave height of 0.5 m.

Night Visual Searches

Only a small data set was found for night visual searches against life raft canopy lights. This was the CCGS Alert. There were only 18 records and the sweep width result was 0.7 nmi. There were other night visual searches for lights conducted by the CCGS Sir William Alexander, however, this data could not be found.

Night visual searches for white strobe lights from UTBs and WPBs combined, yielded a sweep width of 2.0 nmi. The data set consisted of 336 detection opportunities. The data was collected in light conditions with average wind speeds of 9 kn and average wave heights of 0.8 m.

Night visual searches for hand-held red flares by UTBs and WPBs yielded sweep widths of 10.4 nmi and 12.7 nmi respectively. Each data set contained in excess of 200 detection opportunities, however, the data was collected in very light conditions with average wind speeds of 6 kn and average wave heights of 0.5 m.

Night Vision Goggle (NVG) Searches

There were two data sets for NVG searches against PIWs with reflective tape. One data set was collected by USCG UTBs and consisted of 239 detection opportunities. This data set was collected in wind speeds under 10 kn and yielded an average sweep width of .07 nmi. A small data set was collected by the M.V. Nain Banker which consisted of 24 detection opportunities of which none were detected.

NVG searches conducted by USCG UTBs for small boats ranging from 5.5 m to 6.4 m yielded an average sweep width of 0.2 nmi.

NVG searches were conducted from USCG for 4 and 6-person life rafts without reflective tape. With no moon visible average sweep widths were in the order of 0.2 nmi. In moonlit conditions average sweep width for this type of target increased to 0.6 nmi.

NVG searches for 4- and 6-person life rafts with reflective produced average sweep widths ranging from 0.2 nmi to 1.0 nmi. These searches were conducted from USCG UTBS, the CCGS Alert and the USCGC Vigorous. A small data set was also collected from the M.V. Nain Banker that consisted of 16 detection opportunities, however there were no detections.

NVG searches for 4- and 6-person life raft canopy lights produced sweep widths of 4.6 nmi for the CCGS Alert and 6.2 nmi for the USCGC Vigorous. Wind conditions were in the 15-20 kn range with waves averaging 1.8 m.

In most cases, NVGs had better performance in moonlit conditions and performed far better against illuminated targets as opposed to reflective tape.

Surface Radar Searches

The Sperry 127E radar was tested on the CCGS Jackman against 4-person life rafts with and without radar reflectors. Although detection opportunities were small the performance of the radar against targets with reflectors was three times better than the performance against life raft targets without reflectors as measured by sweep width.

The performance of the Sperry 4016 radar against small wooden boats with hi-flyer radar reflectors was in the order of 4.8 m for the conditions encountered.

The performance of the TITAN against PIW targets as measured by sweep width was 1.2 nmi for the conditions encountered versus 0.2 nmi for the Sperry 4016 for the same target. Although data sets were relatively small this is a positive indication that the detection of small targets can be greatly improved though enhancement and processing of the raw radar data.

2.2 Recommendations

Data Base and Software Related

1. Do a re-analysis of the Canadian POD ancillary data assembled during this project for the purpose of deriving further data that would be input into the present POD data base.

This would make the present POD data base more complete and would bring Canadian POD data more in line with the American POD data that has also been assembled during this project. The result could increase the number of variables to be analyzed for platform/target/sensor data sub-sets that contain both Canadian and American POD data and also allow for a more thorough analysis of the Canadian data.

2. Continue with the development of the SARDAS data base in terms of creating a unified leeway data base and software tools for the analysis of such data.

This project has assembled the leeway data collected by the CCG and the USCG since 1992. This data needs to be put into a unified data base similar to the POD data. Data collected prior to 1992 needs to be reviewed and where practical included with the leeway unified data base. Any software tools developed for leeway analysis could also include tools for extracting sub-sets from the data base that could be used for input into the CANSARP evaluation project.

3. The Coast Guard should investigate the establishment of a sweep width data base and sweep width Calculator for inclusion in the CANSARP program.

This recommendation was put forth as part of the final report on the Joint SAR Trails conducted by the CCG and USCG conducted in 1990 on the Canso Bank off Nova Scotia. The report was "Joint Search and Rescue, Canadian Coast Guard and United States Coast Guard Target Detection Experiment – Canso Bank, 1990 Final Report" TP 11654E, March, 1993. It recommended at that time that a data base should be established from the results of the various CCG and USCG SAR detection experiments carried out to date. Included in this data base should be information on search vessels, type of search, type of target, significant parameters affecting searches, regression coefficients of significant parameters, and the ability to easily calculate sweep width given the values of significant parameters.

This recommendation is another logical follow-on to this project on developing a unified data base together with tools for conducting POD analyses and calculation of sweep width.

4. A project should be undertaken to catalogue and assemble the many reports that exist today on POD and Leeway experiments conducted by the CCG and USCG.

The above would be of obvious value to researchers both in and outside the Coast Guard. All reports could be assembled on CD and where practical could include reference material.

5. The Coast Guard should consider initiating a program to establish and maintain a data base of the types of life rafts and/or lifeboats carried by vessels operating in Canadian waters.

These data would help search planners better estimate leeway and total drift and, also, provide a necessary input required to specify search sweep width. This work could start as a regional pilot project in order to obtain an estimate of the scale of a full cataloguing effort and the work required to maintain the data base.

POD Experiment Related

6. Undertake a pilot project to utilize the Marine Simulator in St. John's for conducting SAR target detection experiments.

If this were practical it would allow POD data to be collected at an accelerated rate. The main opposition to this approach appears to be the question: "How close can actual conditions be simulated?" Certain quarters have suggested that results from a simulated search would not be meaningful. The following paragraphs put forth a possible solution that could render search results from a marine simulator to be of significant value.

The basic approach would be to compare the results obtained from a simulated search with known conditions from a completed SAR detection experiment. There exists today complete search experiment data sets that contain all the parameters to re-create a search scenario. A significant data set that comes to mind is the 1990 experiment conducted on the Canso Bank that involved both CCG and USCG search vessels. The availability of such data leads to a solution of the validation problem, independent of simulator fidelity. From the trial data all search parameters can be programmed into the marine simulator. These would include such parameters as search tracks, vessel speed, sea conditions, target location, target type and so forth. The subsequent sweep width results from a simulator search then could be calibrated against sweep results obtained from the field trails.

7. Continue collecting radar search data using standard marine radar for small targets that are equipped with and without radar reflectors.

Several small data sets were collected in 1995 as well as in previous experiments dating back to 1986. This work needs to continue so that a sound sweep baseline can be established for the standard marine radar against common small SAR targets. Even with the advent of new technology such as the MRI and AI Tracker, most vessels today still carry marine radars that use standard processing methods.

8. Continue collecting POD data for new technologies such as the MRI and AI Tracker and develop POD models for these technologies against common small SAR targets.

The above types of new technologies have outperformed a standard marine radar. However, this performance needs to be well documented in a realistic comparison trial by an independent party. If, as is suspected, these new technologies significantly outperform standard radars, this could lead to more support for further R&D, not only within the government but also within the private sector such as the oil industry.

9. Increase the effort to develop POD models for NVG against common small targets.

NVGs have now become more common on CCG vessels.

10. Continue to review and address data collection recommendations put forth in Phases I and II of this three phase project, especially concentrating on those types of vessels from which detection data has already been collected.

By filling out the data collection data sets of selected vessel types this would establish sweep boundaries for other platform/target/sensor combinations.

Leeway Experiment Related

11. Conduct a project that would see leeway models developed for certain common SAR targets followed by a field trail to validate these models.

The leeway dynamics project has used the 1992 and 1993 leeway data sets as development data sets for the development of models for a 4-person life raft and 5.6 m boat. The next logical step is to develop models for common SAR targets for which no data exists. These models should then be validated independently in a field trial. If the models perform well this would lead to an acceleration in the development of leeway models for many common SAR targets and most importantly the search planner can use these models with confidence.

Such a field trial could also be tied into the collection of data for related SAR research.

12. Re-examine the 1992 and 1993 leeway data to determine the influence of waves on the motion of a drifting SAR target.

During 1992 and 1993, a certain amount of wave data were collected in support of these trials. However, waves were not investigated specifically to determine their influence on total drift. It may also be worthwhile to re-examine other issues such as cross wind component or leeway angle over a longer averaging period.

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